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FINAL

**PHASE II REMEDIAL INVESTIGATION REPORT
PASCO LANDFILL
PASCO WASHINGTON**

VOLUME I: TECHNICAL REPORT

**March 13, 1998
Project No. 624419**

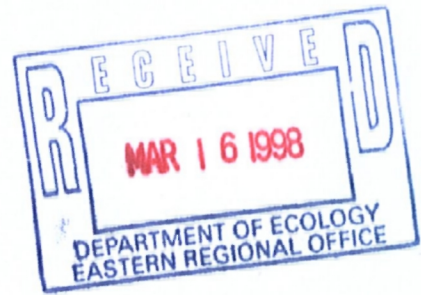
Prepared for:
Pasco Landfill PLP Group



Philip Environmental Services Corporation

P.O. Box 3552, Seattle, WA 98124
955 Powell Avenue S.W., Renton, WA 98055
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List of Abbreviations and Acronyms

BFDHD	Benton-Franklin District Health Department
bgs	below ground surface
CCS	Corrosion Control Specialists
CDD / CDF	Chlorinated Dibenzo-p-Dioxins and Dibenzo Furans
CGI	combustible gas indicator
Chempro	Chemical Processors, Inc.
cm/s	centimeters per second
COD	Chemical Oxygen Demand
E&E	Ecology and Environment, Inc.
Ecology	Washington State Department of Ecology
EM	electromagnetic induction
ERM	ERM-Rocky Mountain, Inc.
FCPD	Franklin County Planning Department
GC	gas chromatograph
GPR	ground-penetrating radar
GSSI	Geophysical Survey Systems Inc.
HDM	Horizontal Dipole Moment
IRM	interim remedial measure
LEL	Lower Explosive Limit
LSA	Landspread Area
MCPA	Methoxone, (4-chloro-O-Tolyoxy)Acetic Acid
MEK	acetone, 2-butanone
mg/l	milligrams per liter
MIBK	4-methyl-2-pentanone
MTCA	Model Toxics Control Act
NAD	North American Datum
NGA	Northwest Geophysical Associates
NGVD	National Geodetic Vertical Datum
NPL	National Priorities List
OCDF	Octachloro Dibenzo Furan
ohm-cm	ohms - centimeter
PCB	Polychlorinated Bi-Phenyl
PCE	Tetrachloroethene
Philip	Philip Environmental Services Corporation
PID	photoionization detector
PPE	personal protection equipment
ppm	part per million
PSL	Pasco Sanitary Landfill
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation Recovery Act
RI	Remedial Investigation
RRC	Resource Recovery Corporation
SAP	Sampling and Analysis Plan
SMA	Sludge Management Area
SP	self potential (survey)
SVE	soil vapor extraction
SVOC	semivolatile organic compound
TC Organics	Toxicity Characteristic Organics
TCDF	Tetrachloro Dibenzo Furan
TCE	Trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TEF	toxicity equivalence factor

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TOC	Total Organic Carbon
µg/l	micrograms per liter
USEPA	United States Environmental Protection Agency
VDM	Vertical Dipole Moment
VDM/HDM	Vertical and Horizontal Dipole Modes
VOC	volatile organic compound

EXECUTIVE SUMMARY – PASCO LANDFILL SITE

This report summarizes the results of the Phase II Remedial Investigation (RI) conducted at the Pasco Landfill Site (the site) near Pasco, Washington. This work was completed by Philip Environmental Services Corporation (Philip) on behalf of the Pasco Landfill Potentially Liable Person (PLP) Group, in accordance with Enforcement Order DE94TC-E103 and amendments issued by the Washington State Department of Ecology (Ecology). The objective of this report is to document the Phase II activities and present an evaluation of the nature and extent of contamination at the site. The scope of this Phase II RI Report complies with the provisions of WAC 173-340-350(5) and, when coupled with the Phase I Report, has collected, developed, and evaluated sufficient information to proceed to the preparation of a Risk Assessment/Cleanup Levels Analysis and development of a Feasibility Study. Together, these documents will provide the basis for development of the Cleanup Action Plan for the site.

HISTORY OF SITE USAGE

The site initially operated as an open burning facility with limited solid waste recovery and recycling operations. The burning of refuse occurred in trenched areas at the site during the 1960s and early 1970s. After burning was discontinued, municipal waste disposal activities continued with the operation of a sanitary landfill until June 1993.

In 1972, Resource Recovery Corp. (RRC) was formed to operate a new industrial waste disposal facility at the site. Ecology issued State Waste Discharge permit No. 5301 to RRC for industrial waste disposal at the site, which occurred from April 1972 through December 1974. The industrial waste operation accepted primarily bulk sludges and drummed wastes for disposal. Industrial waste disposal was segregated into five primary zones at the site designated as Zones A, B, C, D, and E. Adjacent agricultural community concerns over the operation of the industrial waste disposal facility, primarily acceptance of herbicide wastes, resulted in the termination of the use of the site as an industrial waste disposal facility in December 1974. Closure of the industrial waste portion of the site began in 1975 and was completed in 1980.

OVERVIEW OF RI INVESTIGATION

Site investigation activities have been conducted at the site under the supervision of Ecology, the USEPA, or their contractors since 1984 to assess potential releases of hazardous substances to the environment. The site was nominated to the National Priority List (NPL) of Superfund sites by USEPA in June 1988 and placed on the NPL in February 1990. Phase I of the Remedial Investigation (RI) was begun in 1992, and was completed with the submittal of the Final Phase I RI Report in 1994. The Phase II RI activities began in May 1995. During the summer of 1995, it was determined that off-site groundwater had been impacted by releases from the site. This determination resulted in an increase in scope of the Phase II RI to include an expanded off-site groundwater investigation and identification of potentially impacted residential wells located hydraulically downgradient from the site.

During the Phase I and Phase II RI Investigations, geophysical investigations were conducted using ground penetrating radar, ground magnetics, and electromagnetic induction to identify the extent of various source areas. Hydrogeological parameters have been evaluated by conducting a pumping test and analyzing soil samples for moisture content, hydraulic conductivity, porosity and permeability.

Soil analyses have included various physical parameters, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), metals, herbicides, dioxins/dibenzofurans, and radionuclides. Samples of bulk waste materials from Zones C, D, and E have been collected and analyzed for characterization in accordance with Washington Dangerous Waste (WAC 173-303) and Federal Resource Conservation and Recovery Act (RCRA) regulations. Soil gas has been investigated and analyzed for VOCs, oxygen, carbon dioxide, methane, and acid gas.

A total of 51 groundwater monitoring wells were sampled during the Phase II RI to evaluate potential impacts from historical disposal activities at the site. Groundwater samples were analyzed for VOCs, SVOCs, herbicides, Appendix I metals, Appendix II metals, and water quality parameters. Thirty-five groundwater monitoring wells are currently being sampled quarterly as part of the ongoing groundwater monitoring program. The results of these analyses are reported to Ecology and the Benton-Franklin District Health Department in the quarterly and annual Groundwater Monitoring Reports for the site.

Based on the results of the Phase I and II RI Activities, the following Interim Remedial Measures (IRMs) were implemented at the site during 1996 and 1997:

1. Provision of bottled drinking water to all well users in the area potentially impacted by the off-site groundwater contamination pending further investigation of the contaminant plume.
2. Extension of the Lewis Street public water main to connect those users whose wells were impacted by groundwater contamination to the City of Pasco public water supply system in order to preclude residential exposure to contaminated groundwater.
3. Installation of a pilot-scale Soil Vapor Extraction (SVE) system to treat source areas and limit the transport of contaminants from source areas to groundwater.
4. Installation of a pilot-scale NoVOCs™ groundwater treatment system to remove volatile organic compounds (VOCs) from groundwater and limit off-site migration of contaminants.

A complete discussion of each of these IRMs can be found in the *Interim Measures Completion Report, Pasco Landfill* (Philip Environmental, 1998) previously submitted to Ecology.

PHYSICAL SETTING

An analysis of geologic and hydrogeologic data collected from the Pasco Landfill site and other areas of the Pasco Basin indicates that four broad hydrostratigraphic units are present in the subsurface. These units are:

1. the unsaturated zone (including eolian sands, Touchet beds, and unsaturated portions of the Upper Pasco Gravels);
2. the unconfined aquifer system (including saturated portions of the Lower Pasco Gravels and the Middle Ringold formation);
3. the confining layer (made up of the Lower Ringold Formation and low permeability flows of the Columbia River Basalt); and
4. the confined aquifer system (made up principally of the more permeable interflow and interbed zones of the Columbia River Basalt Group).

The surface of the groundwater in the unconfined aquifer system occurs 20 to 80 feet below the ground surface. The groundwater flows to the south and southwest beneath the site. Horizontal gradients and hydraulic conductivity at the site show average seepage velocities ranging from a high of 16.6 ft/day in the central portion of the site to a low of 4 ft/day south and

down-gradient from the site. Analysis of vertical gradients in the immediate vicinity of the site show no apparent trends.

REVIEW OF SITE SOURCE AREAS

A brief summary of the history and conclusions regarding the extent and nature of contamination in the former Municipal Landfill and each primary disposal zone are provided below. The discussion of individual waste zones begins with the former Municipal Landfill and proceeds from the northeast to the southwest, and continuing off-site, generally in the predominant direction of groundwater movement.

MUNICIPAL LANDFILL

The site was converted from open burning to a sanitary landfill in 1971. Waste disposal activities at the former Municipal Landfill consisting of the acceptance of agricultural, septic, industrial, and municipal waste occurred from 1971 until May 1993 when it was closed with an interim cover consisting of approximately three feet of native soil. A Landfill Closure Plan for the former Municipal Landfill containing final cover and landfill gas extraction design specifications was approved by Ecology and the Benton-Franklin District Health Department in May 1997 (Woodward-Clyde Consultants, 1997).

Evaluation of groundwater monitoring data indicates that VOCs migrating from waste in the former Municipal Landfill are impacting groundwater at the site. Analysis of landfill gas data reveals the presence of elevated concentrations of methane accompanied by depressed oxygen concentrations along the western boundary of the former Municipal Landfill, indicating that biological degradation of the waste is occurring. The data also indicate that a soil-gas plume containing VOCs has extended beyond the boundaries of the former municipal landfill and may be impacting groundwater in other areas of the site.

ZONE E AND ZONE TS-1

Waste disposal activities at Zone E occurred from about July 1973 to December 1974 and consisted primarily of the disposal of about 11,000 tons of chlor-alkali waste. Zone TS-1 was used for temporary storage of chlor-alkali sludge prior to placement in Zone E.

Groundwater contaminated with VOCs and metals occurs beneath Zone E. However, the results of the Phase II Bulk Waste Characterization Analyses, the additional Zone E waste profiling analyses conducted during May 1997, and the evaluation of the location, timing, and concentration of each detected VOC and metal indicates that their presence in groundwater is not associated with Zone E. Together, these data indicate that Zone E is not acting as a significant source of contaminants in groundwater.

ZONES C AND D

Waste disposal activities at Zone C occurred from about October 1972 until December 1974. Zone D was constructed around August 1973 and received waste until approximately December 1974. Wastes deposited in Zones C and D consisted of approximately three million gallons of bulk plywood resin waste, wood treatment and preservative waste, lime sludge, cutting oils, paint and paint solvent waste, and other bulk liquid waste.

Groundwater contaminated with solvents occurs beneath Zones C and D. However, each of the 20 VOCs detected in Zone C and D Wells during Phase II sampling was also detected in wells upgradient from Zones C and D; 18 of the 20 VOCs were also detected in soil-gas samples from the areas adjacent to Zone A and the Municipal Landfill. The evaluation of the location, timing, and concentration of each VOC detected in the bulk waste material, in soil from beneath the zones, and in adjacent groundwater monitoring wells indicates that their presence in groundwater, with the possible exception of xylenes, is not associated with Zones C and D. Together, these data indicate that Zones C and D are not acting as significant sources of VOCs in groundwater.

ZONE B

Waste disposal activities at Zone B occurred from December 1972 until October 1973, and consisted of the disposal of approximately 5,000 drums of 2,4-D tar, MCPA-bleed, and other herbicide manufacturing waste.

No herbicides were detected in any soil samples collected from the area adjacent to Zone B. Although some dioxin congeners were detected above background concentrations in soil

samples collected from the area adjacent to Zone B, no dioxin congeners were detected above MTCA Method B formula values in any Zone B soil samples.

A total of 16 VOCs were detected in Zone B Wells. However, 14 of the 16 VOCs detected in the Zone B Wells were only detected during one sampling event (June 1995) and 10 of the 16 VOCs detected in Zone B Wells were also detected in up-gradient background wells during the same sampling event. These data indicate that Zone B is not acting as a source of VOCs in groundwater.

ZONE A/ NORTH-SOUTH BURN TRENCH/ BALEFILL

Disposal and burning of refuse occurred in the North-South Burn Trench between July 1961 and May 1963. Waste disposal activities at Zone A consisted of disposal of approximately 40,000 drums of solvents, paints, cleaners, and other industrial waste between April 1972 and December 1974. An interim cap consisting of polyethylene sheeting covered with soil cover of unknown thickness was placed over Zone A in 1976. An additional soil cap approximately two feet thick was placed over the Zone A in 1980. Disposal of baled municipal waste occurred in the Balefill Area between May 1976 and May 1989.

Evaluation of groundwater monitoring data indicates that VOCs migrating from waste in Zone A are impacting groundwater at the site. Analysis of soil-gas data reveals the presence of elevated concentrations of methane accompanied by depressed oxygen concentrations in the vadose zone surrounding Zone A, indicating that biological degradation of the waste is occurring. The data also indicate that a soil-gas plume containing VOCs has extended beyond the boundaries of Zone A and may be impacting groundwater in other areas of the site.

CONCLUSIONS

SITE SOIL AND SOIL-GAS

Analysis of soil data indicates that there has been no significant impact to the soils outside the footprint of the former Municipal Landfill and the primary disposal zones. Soil-gas analysis shows a large zone of VOC contaminated soil gas surrounding the former Municipal Landfill and Zone A.

SITE GROUNDWATER

The results of the Phase II RI show that shallow groundwater (within 50 feet of the groundwater surface) at the site has been impacted by VOCs (primarily chlorinated VOCs) migrating from the wastes within the former Municipal Landfill and Zone A. The deeper groundwater does not appear to be impacted.

OFF-SITE GROUNDWATER

Impacts to off-site groundwater from the site were first discovered in the summer of 1995. The results of the Phase II RI and ongoing groundwater monitoring programs indicate that VOCs in excess of MTCA Method B formula values are present in groundwater hydraulically down-gradient from the site. Analysis of the Phase II RI and ongoing groundwater monitoring data indicate that the impacts to off-site groundwater have resulted from releases of VOCs from Zone A and the former Municipal Landfill.

PROJECT STATUS

As a result of completing the Phase II RI, sufficient information has been collected, developed and evaluated regarding the extent and nature of contamination at the Pasco Landfill Site to allow preparation of a Risk Assessment/Cleanup Levels Analysis and development of a Feasibility Study and Cleanup Action Plan for the site.

1 INTRODUCTION

This report summarizes the results of the Phase II Remedial Investigation (RI) conducted at the Pasco Landfill site (the site) near Pasco, Washington. This work was completed by Philip Environmental Services Corporation (Philip) on behalf of the Pasco Landfill Potentially Liable Person (PLP) Group, in accordance with Enforcement Order DE94TC-E103 and amendments issued by the Washington State Department of Ecology (Ecology). The objective of the report is to document the Phase II RI activities and present an evaluation of the nature and extent of contamination at the site. The Phase II RI report builds on the findings presented in the Phase I RI Report (Burlington Environmental Inc., 1994).

The scope of work for the Phase II RI was specified in the Enforcement Order as Exhibit B. The Phase II RI activities were performed in accordance with project work plan documents approved by Ecology, including the Phase II Work Plan (Volume I) (Burlington Environmental Inc, 1995a); Sampling and Analysis Plan (Volume II) (Burlington Environmental Inc, 1995b); Data Management Plan (Volume III) (Burlington Environmental Inc, 1995c); Health and Safety Plan (Volume IV) (Burlington Environmental Inc, 1995d); and Public Participation Plan (Volume V) (Burlington Environmental Inc, 1995e).

1.1 REPORT ORGANIZATION

This RI report has been subdivided into five volumes. Volume I is the technical report, with Volume II containing the figures and tables for the report. Volumes III through V contain appendices, including supplemental information such as field methodology, boring logs, reference documents, and analytical data summaries.

Volume I has been subdivided into four sections. In addition to the Introduction, Section 1 provides general site background information, including regional meteorology, geology, hydrogeology, surface water hydrology, an abbreviated site history, a discussion of the individual waste zones at the site, and a review of the Phase II RI objectives.

Sections 2, 3, and 4 contain discussions of the Phase II field activities, the results of the activities, and the conclusions reached, respectively. In each section, sitewide geological and hydrogeological activities are presented first followed by detailed discussions by individual waste

zone. The discussion of individual waste zones begins with the Municipal Landfill and proceeds from the northeast to the southwest, and continuing offsite, generally in the predominant direction of groundwater movement.

1.2 SITE BACKGROUND

The site is located approximately 1.5 miles northeast of the City of Pasco, in the southwest quarter of Section 15, the northeast quarter of Section 21 and the northwest quarter of Section 22, Township 9 North, Range 30 East, Willamette Meridian, in Franklin County, Washington (Figure 1-1 and Figure 1-2). The site occupies a 200-acre area consisting of gently rolling hills surrounded by rangeland and irrigated cropland. North of the site is the New Waste, Inc. an operating permitted solid waste landfill.

1.2.1 LAND USE, CULTURAL FEATURES, AND DEMOGRAPHY

The land use, cultural features and demography of the Pasco Landfill site and adjacent areas were characterized as part of the Phase I RI. The site and immediate surrounding area are zoned for agriculture and commercial use. Details can be found in the Phase I RI Report (Burlington Environmental, 1994).

1.2.2 METEOROLOGY

The site is located in an arid region of the Columbia Plateau with a mean annual precipitation of approximately 7.5 inches. Mean monthly temperatures range from a high of approximately 90 degrees Fahrenheit in the summer to a low of 26 degrees Fahrenheit in the winter. Winds in the area average less than 10 miles per hour (National Oceanic and Atmospheric Administration, Kennewick Station, 1992). A more detailed description of the meteorology of the site can be found in the Phase I RI Report (Burlington Environmental, 1994).

1.2.3 REGIONAL GEOLOGY

The Pasco Landfill site is located in the central portion of the Columbia Plateau, a broad plain situated between two mountain ranges, the Cascade Range to the west and the Rocky

Mountains to the east. The Columbia Plateau occupies an area of about 64,500 square miles, mainly in eastern Washington and northeastern Oregon (Figure 1-3). Geological events that shaped the site are similar to those that affected all of eastern Washington and include:

- Eruption of flood lavas of the Columbia River Basalt Group from southeastern Washington;
- Explosive volcanism and sediment transport from the ancestral Cascade Range that produced fluvial deposits across the Columbia Plateau;
- Compressional tectonics that formed east-west oriented folds in the basalt;
- Catastrophic glacial flooding that scoured channels into the basalt and left behind sand and gravel deposits; and
- Deposition of thick layers of wind-deposited silt (loess) from winds moving southwest to northeast across the plateau.

The dominant rocks of the Columbia Plateau are the Miocene basalts and sedimentary interbeds of the Columbia River Basalt Group which range in thickness from 4,000 to 12,000 feet in the Pasco Basin. The Columbia River Basalt Group is overlain by the younger Pliocene rocks of the Ringold Formation, deposited as mainstream and sidestream facies of the ancestral Columbia River, and the loess deposits of the Palouse Formation. The Ringold Formation is overlain by glaciofluvial sediments of the Hanford Formation, deposited as a result of the catastrophic flooding from glacial Lake Missoula during the Pleistocene. The Hanford Formation is further subdivided into the coarse deposits of the Pasco Gravels and the fine-grained slack-water deposits of the Touchet Beds. Table 1.1 shows the regional stratigraphy for the Columbia Plateau. A more detailed description of the regional geology of the Pasco Landfill site and adjacent areas is provided in the Phase I RI Report (Burlington Environmental, 1994).

1.2.4 REGIONAL HYDROGEOLOGY

Regional aquifers in this part of the Columbia Basin are present in the Columbia River Basalt Group and the unconsolidated deposits. The Columbia River Basalt Group is the principal aquifer of the Columbia Plateau, consisting of a thick sequence of flood basalts with associated interbedded sedimentary layers. The thickness of the basalt sequence exceeds 11,000 feet in some areas of the basin.

Individual basalt flows within the sequence range in thickness from 20 to 100 feet with water occurring in zones along the tops and bottoms of the flow zones. Irrigation wells that penetrate multiple interflow zones in the basalt aquifer are often capable of producing water at rates from 1,000 to 2,500 gallons per minute (gpm).

Many basalt flows are interbedded with fine-grained sedimentary deposits. These interbeds often exhibit low permeability and retard the movement of water between interflow zones. The vertical permeability through the basalt flows is generally lower than the horizontal permeability. The transmissivity in the region has been reported to range from 500 to 7,400 square feet per day (ft^2/d), averaging about 2,600 ft^2/d (Tanaka and others, 1974).

Stratified clay, silt, sand, and gravel of the Ringold Formation and glaciofluvial deposits of the Hanford Formation overlie the basalt over much of the region. Loess deposits may also overlie the basalt, but when present are usually thin. Where the saturated thickness of the glaciofluvial deposits is great, high yields of water can be expected. Well yields from 10 to 1,000 gpm are reported for the Ringold Formation, while well yields from 100 to 4,000 gpm have been reported for the glaciofluvial sands and gravels. Silt content often limits the yield of wells in the Ringold Formation; however, in the vicinity of the site, higher yields can occur due to the presence of thicker, coarse-grained glaciofluvial deposits in the Pasco syncline.

The hydraulic conductivity of the Ringold Formation has been reported to range from 0.007 to 0.21 centimeters per second (cm/s), and that of the glaciofluvial deposits has been reported to range from 0.18 to 7.0 cm/s (U.S. Department of Energy, 1979).

The primary source of recharge water to the confined aquifers of the Columbia River Basalt Group is precipitation in the northeast areas of the Columbia Plateau where precipitation exceeds 18 inches annually, compared to about 7 inches at the site. Regional groundwater east of the Columbia River flows to the southwest, following topography and discharges along the Columbia and Snake Rivers (Widness, 1986). The unconfined aquifer in the Ringold Formation and the glaciofluvial deposits are also recharged from the precipitation in the higher elevations surrounding the Pasco Basin, as well as downward percolation from the tributaries that originate in the hills and mountains (U.S. Department of Energy, 1979).

Direct recharge of the unconfined aquifer also occurs in agricultural areas through the infiltration of irrigation water. The U.S. Bureau of Reclamation (1971) has estimated that 20

to 40 percent of irrigation water reaches the water table during periods of prolonged irrigation. Similarly, Bauer and Viccaro (1990) calculated that from an estimated 23.7 inches of irrigation water applied to agricultural areas in the Pasco Basin annually, approximately 12 inches reach the regional aquifer system through direct infiltration.

However, the results of water balance studies of the region indicate that infiltration of rainfall does not contribute appreciably to recharge of the aquifer on an annual basis. Numerical modeling of 36 years of hydraulic data for the Cold Creek and Dry Creek Basins on the Hanford Site (Dincola 1997) (located approximately 40 miles from the site), indicated an average of approximately 0.1 inches of recharge from runoff annually. The results of a water balance model prepared for the region by Fenn et al. (1975) indicated that on a net monthly basis no free water from infiltration of precipitation was available for recharge to the aquifer. Similarly, based on an estimated area of 1,200,000 acres for the Pasco Basin, numeric modeling of the basin's hydrologic budget by Gephart et al. (1979) indicated that of 7.56 inches (756,000 acre-feet) of annual precipitation, 7.50 inches (750,000 acre feet) were removed through evapotranspiration leaving only 0.06 inches (6,000 acre-feet) available for infiltration. Bauer and Viccaro (1990) calculated slightly higher rates for recharge, with values ranging between 0.3 and 0.5 inches annually for undeveloped (non-irrigated) portions of the Pasco Basin. Bauer and Viccaro employed the deep percolation model, which utilizes daily temperature, soil type, evapo-transpiration, precipitation, and other climatological data to produce time-averaged estimates of recharge from infiltration of precipitation. This use of daily measurements for estimating infiltration can be significant in arid regions, such as the Pasco Basin, where precipitation is infrequent and may account for the higher estimates of annual recharge rates calculated in this study.

Additional details concerning the regional hydrogeology of the Pasco Landfill site and surrounding area are provided in the Phase I RI Report (Burlington Environmental, 1994)

1.2.5 SURFACE WATER HYDROLOGY

The nearest body of surface water to the Pasco Landfill is a man-made dairy pond located approximately 1,500 feet southeast of the site on the Tomlinson Dairy property. This pond is relatively shallow (less than six feet deep) and is not considered a discharge point for shallow

groundwater in the area. Groundwater in the vicinity of the site discharges to either the Columbia River (Lake Wallula, approximately three miles southwest of the site) and the Snake River (approximately 2.5 miles southeast of the site).

1.3 SITE HISTORY

Throughout the history of the site, waste disposal activities were conducted under permits issued by the Benton-Franklin District Health Department (BFDHD), the Franklin County Planning Department (FCPD), and Ecology. A summary of waste management activities at the site is provided in Table 1.2 and discussed briefly below. A complete discussion of the site history can be found in the Phase I RI Report (Burlington Environmental, 1994).

The site was initially operated as an open burning facility by Mr. John Dietrich, doing business as Pasco Garbage Service from 1958 to 1971. Burning of refuse occurred in two or three trenched areas at the site during the 1960s and early 1970s.

Chemical Processors, Inc. (Chempro), a Seattle-based solvent recycling company, and the Dietrichs (John, Larry, and Leonard) formed Resource Recovery Corporation (RRC) in 1972 for the purpose of operating a new industrial waste disposal facility.

Ecology issued State Waste Discharge Permit No. 5301 to RRC for industrial waste disposal at the site, which occurred from April 1972 through December 1974. The industrial waste operation accepted primarily bulk sludges and drummed wastes for disposal. Industrial waste was segregated into five primary zones at the facility designated as Zones A, B, C, D, and E. Agricultural community concerns over the operation of this facility, primarily due to the acceptance of herbicide wastes, resulted in termination of the site as an industrial waste disposal facility in December 1974. Closure of the industrial part of the site began in 1975 and was completed in 1980.

During the period of industrial waste disposal, Municipal Landfill operations including disposal of various bulk liquids, septic tank wastes, sewage sludges, and animal fat emulsions continued at the site. These wastes were placed in lagoons or spread over ground surface areas at two locations on the site. At times, landspread wastes were mixed with soil for use as daily cover for the Municipal Landfill. Another area of the site was used for the disposal of large quantities of baled refuse as part of the municipal waste disposal operations.

In 1981, Pasco Sanitary Landfill, Inc. (PSL), owned by Mr. Larry Dietrich, was formed to operate the site. In 1982, groundwater monitoring wells were installed by JUB Engineers for PSL pursuant to an order from Ecology. Those wells, in addition to wells installed after 1982 to monitor the Municipal Landfill, have been sampled regularly in accordance with State of Washington Minimum Functional Standards for Solid Waste Facilities (WAC 173-304) and the Municipal Landfill permit.

The site was investigated in 1984 as part of the United States Environmental Protection Agency's (USEPA's) nationwide dioxin investigation because of known herbicide wastes buried there. No dioxin contamination or other organic contaminants were identified in the site groundwater during that investigation. Ecology and Environment, Inc. (E&E) performed another site investigation in 1985 for the USEPA and identified several volatile organic compounds (VOCs) in groundwater beneath the site.

In June 1988, the USEPA nominated the Pasco Landfill site to the National Priorities List (NPL) of proposed Superfund sites. The site was formally included on the NPL in February 1990.

Phase I of the RI was begun in 1992, and completed with the submittal of the final Phase I RI report in 1994. This investigation identified certain data gaps and additional work needed to provide sufficient data to complete the RI and develop the FS for the site. A summary of past site investigation activities is provided in Table 1.3.

1.4 WASTE DISPOSAL ZONES

This section provides a discussion of waste disposal activities for each zone at the site. Information provided below was summarized from the site history provided in the Phase I RI Report (Burlington Environmental, 1994). The locations of waste management areas are shown in Figure 1-4. A summary of documented waste disposal to the industrial waste disposal zones is contained in Table 1.4.

1.4.1 MUNICIPAL LANDFILL

Municipal waste disposal activities at the site occurred from May 1958 until June 1993, and consisted of refuse burning and disposal of septic and solid wastes. The site operated as an

open burning facility from 1958 to 1971. Refuse burning was discontinued in 1971, when the site was converted to a sanitary landfill. Agricultural waste placed in the Municipal Landfill between 1969 and 1972 may have included pesticides and herbicides. Dried sludges from the former sewage lagoons SL-2 and SL-3 were deposited in the Municipal Landfill sometime after August 1990.

Beginning in May 1993, an interim cover consisting of at least three feet of native soil was placed over the former Municipal Landfill. A Landfill Closure Plan containing final cover and landfill gas extraction design specifications was approved by Ecology and the Benton-Franklin District Health Department in May 1997 (Woodward-Clyde Consultants 1997).

1.4.2 EAST-WEST BURN TRENCHES BT-1

Disposal and burning of refuse began in two east-west burn trenches, sometime between May 1958 and July 1961. Water was applied periodically to cool the area so that additional refuse could be added. By May 1963 the trenches were nearly full. Disposal and burning had ceased by May 1965.

1.4.3 LAGOONS SL-2 AND SL-3

Lagoons SL-2 and SL-3 were used for disposal of septic tank and chemical toilet pumpings from May 1979 until sometime before May 3, 1989. Lagoon SL-3 was constructed by May 1980, to accommodate overflow from lagoon SL-2. In August 1990, dried sludges were excavated from both lagoons and moved to the Municipal Landfill. The area encompassing the lagoons was regraded in the spring of 1991, an irrigation sprinkler was installed, and the area was planted with potatoes. In late August 1991, the irrigation and agricultural activities were discontinued.

1.4.4 SLUDGE MANAGEMENT AND LANDSPREAD AREAS

Waste disposal activities at the Landspread and the Sludge Management Areas consisted of land spreading of sewage sludges and animal fat emulsion coolants, from April 1981 until 1989. In 1989, sludge spreading activities continued on the area north of the Municipal Landfill

face (the Sludge Management Area), but apparently had been discontinued in the area south of the sewage lagoons SL-2 and SL-3 (Landspread Area).

1.4.5 ZONE E AND ZONE TS-1/SL-1

Waste disposal activities at Zone E occurred from about July 1973 to December 1974 and consisted primarily of the disposal of approximately 11,000 tons of chlor-alkali waste.

Zone TS-1 was used for temporary storage of chlor-alkali sludge prior to placement in Zone E. It is likely that all chlor-alkali waste shipped to the site prior to October 1973 was stored temporarily in TS-1 or TS-2.

Sometime between early 1975 and late May 1976, the chlor-alkali sludge stored in the temporary storage area TS-1 was transferred to Zone E. Zone TS-1 was then renamed as sewage lagoon SL-1 and was used for disposal of septic tank and chemical toilet pumpings from May 1976 until its closure in June 1979.

Zone E was capped with polyethylene sheet and a soil cover of undetermined thickness in 1976. A final soil cover, approximately two feet thick, was placed over the Zone in 1980.

1.4.6 ZONES U-1 AND TS-2

Waste disposal activities at Zone U-1 consisted of the disposal of small quantities of plywood resin waste, wood treatment and preservative waste, lime sludge, cutting oils, paint and solvent waste, and other bulk liquid waste between October 1973 and sometime in 1975. An initial soil cover, approximately three feet thick, is reported to have been placed over the zone at about early 1975.

Zone TS-2 was used for temporary off-loading and storage of chlor-alkali sludge, prior to moving the waste into the southern cell of Zone E by May 1976. Off-loading to Zone TS-2 may have begun by July or October of 1973. An initial soil cover, approximately three feet thick, is reported to have been placed over Zone TS-2 in about 1974.

1.4.7 ZONES C AND D

Waste disposal activities at Zone C began in about October 1972 and continued until December 1974. Zone D was constructed in approximately August 1973 and probably first received waste in September 1973. Waste deposited in Zones C and D consisted of approximately three million gallons of bulk plywood resin waste, wood treatment and preservative waste, lime sludge, cutting oils, paint and paint solvent waste, and other bulk liquid waste.

Zones C and D were capped with polyethylene film and a soil cover of undetermined thickness in 1976. A final soil cover, approximately two feet thick, was placed over the zones in approximately 1980.

1.4.8 ZONE B

Waste disposal activities at Zone B occurred from December 1972 until October 1973, and consisted of the disposal of approximately 5,000 drums of 2,4-D tar, MCPA-bleed, and other herbicide waste. A polyethylene cap and a soil cover of unknown thickness were reportedly placed over the Zone in 1976. A final soil cover, approximately two feet thick, was placed over Zone B around 1980.

1.4.9 ZONE A/NORTH-SOUTH BURN TRENCH/BALEFILL

Waste Disposal activities in this area consisted of refuse burning in the North-South Burn Trench, drum disposal in Zone A, and disposal of baled municipal waste in the Balefill Areas. Disposal and burning of refuse occurred in the North-South Burn Trench between July 1961 and May 1963. Water was applied periodically to the trench to cool the burning refuse. Raw refuse is believed to have been placed over the trench in May 1965.

Waste disposal activities at Zone A occurred from April 1972 to December 1974 and consisted of disposal of approximately 40,000 drums of solvents, paints, cleaners, and other industrial waste. Many of the early drums were reported to have been in poor condition and leaked prior to, or upon disposal as a result of impact with the ground or with previously disposed of materials.

In 1976, a polyethylene cap was placed over Zone A, with an initial soil cover of unknown thickness. A final soil cover, approximately two feet thick, was placed over the zone in 1980.

Some time between May 1976 and June 1977, baled municipal waste disposal (balefill) began in the Balefill Area immediately east of Zone A. In late spring 1980, a fire broke out in the Balefill Area and reportedly burned for over a week before it was extinguished. During the fire, the area was disturbed by heavy equipment and a large volume of water was applied to the burning bales. Disposal of waste in the Balefill Area ceased by May 1989.

1.5 REMEDIAL INVESTIGATION OBJECTIVES

Phase I of the Remedial Investigation (RI) was begun in 1992, and was completed with the submittal of the Final Phase I RI Report in 1994. The Phase II RI activities began in May 1995. The objectives of the Phase II RI, as stated in the Phase II RI Work Plan, were to:

- Investigate the nature and extent of contamination in the Industrial Waste Areas;
- Characterize the drummed and bulk wastes found in the Industrial Waste Areas;
- Analyze trends in groundwater contamination, including seasonal variability in groundwater hydrogeology, contaminant transport, and groundwater chemistry;
- Investigate the nature and extent of landfill gas migration; and
- Investigate whether groundwater contamination has migrated offsite and if so, determine as appropriate the nature and extent of contamination.

During the summer of 1995, it was determined that off-site groundwater had been impacted by releases from the site. This determination resulted in an increase in the scope of the Phase II RI to include an expanded off-site groundwater investigation and identification of potentially impacted residential wells located hydraulically downgradient from the site.

Based on the results of the off-site groundwater investigation and other RI activities, the following Interim Remedial Measures (IRMs) were implemented at the site during 1996 and 1997:

1. Provision of bottled drinking water to all well users in the area potentially impacted by the off-site groundwater contamination pending further investigation of the contaminant plume.

2. Extension of the Lewis Street public water main to connect those users whose wells were impacted by groundwater contamination to the City of Pasco public water supply system in order to preclude residential exposure to contaminated groundwater.
3. Installation of a pilot-scale Soil Vapor Extraction (SVE) system to treat source areas and limit the transport of contaminants from source areas to groundwater.
4. Installation of a pilot-scale NoVOCs™ groundwater treatment system to remove volatile organic compounds (VOCs) from groundwater and limit off-site migration of contaminants.

The results of the Soil Vapor Extraction Treatability Study were submitted to Ecology as a Technical Memorandum in September 1995 (Philip 1995). A complete discussion of the SVE system and each of the other IRMs is contained in the *Interim Measures Completion Report, Pasco Landfill* (Philip Environmental, 1998) submitted to Ecology during February 1998.

The scope of this Phase II RI Report complies with the provisions of WAC 173-340-350(5) and, when coupled with the Phase I Report, has collected, developed, and evaluated sufficient information to proceed to the preparation of a Risk Assessment/Cleanup Levels Analysis and development of a Feasibility Study for the site. Together these documents will provide the basis for development of the Cleanup Action Plan for the site.

2 REMEDIAL
INVESTIGATION ACTIVITIES

2 REMEDIAL INVESTIGATION ACTIVITIES

This section provides a summary of the Phase II site investigation activities which began in the Spring of 1995. Activities relating to sitewide geological and hydrogeological data acquisition are presented first, followed by a discussion of investigation activities by individual waste zone. Table 2.1 presents a listing of Phase II investigation activities by investigation method, and is arranged in the same order presented in the Phase II Sampling and Analyses Plan (SAP) (Burlington Environmental Inc., 1995b)

Documentation of field investigation activities including site supervisor daily activity logs, sample control and chain-of-custody logs, well development and sampling logs, and other miscellaneous written documentation for the RI are contained in the project file at Philip's Seattle office. These are available to Ecology upon request. Detailed descriptions of field exploration methods are provided in Appendix A.

2.1 GEOLOGY

Shallow and deep soil boring sampling activities were included as part of the Phase II field work. A discussion of these activities, detailing the tasks applicable to each individual waste zone at the site, is provided later in this section. One upgradient offsite ground water monitoring well (MW-25S), six onsite wells (MW-23S, MW-24S, MW-26S, MW-27S, MW-28S and MW-12ID), fourteen offsite down gradient wells (MW-29S through MW-42S), seven soil borings (B-13 through B-15 and B-17 through B-20), two landfill gas probe clusters (LFG-03 and LFG-04), and nine vapor extraction and monitoring wells (VEW, VMW-S, and VMW-D series wells) were installed during the Phase II field work. Onsite well and boring locations are provided in Figure 2-1. Soil samples from all borings, including those completed as monitoring wells, were collected for geologic logging. Geologic logs are provided in Appendix B.

Selected soil samples were tested for physical and engineering characteristics to provide data for subsequent fate and transport evaluations (e.g., potential vadose zone transport modeling, assessment of applicable remedial systems, etc.). These tests included grain size analysis, cation exchange capacity, moisture content, Atterberg limits, total organic carbon, Modified Proctor (Touchet Beds only), and permeability. Two samples (one from the Touchet

Beds and one from the Upper Pasco Gravels) were collected from each of the following: MW-23S, MW-24S, MW-26S, MW-27S, MW-28S, and VEW-01. Duplicate samples from each formation were collected from boring MW-23S. A summary of the physical and engineering soil tests performed, and analytical methodology used is provided in Table 2.2.

Samples for grain size analysis, Atterberg limits, total organic carbon, and cation exchange capacity were collected using stainless-steel split-spoon samplers, transferred to the appropriate sample jars, labeled, and sealed for delivery to the analytical laboratory. Undisturbed samples were collected for permeability, moisture content, and Modified Proctor using 3-inch diameter stainless-steel samplers with brass inner sleeves. Following sample collection, the ends of each sleeve were sealed with wax, wrapped in duct tape, labeled, and packed upright in a cooler for shipment to a geotechnical laboratory for testing.

All new monitoring wells, soil borings, landfill gas probes, vapor extraction wells, vapor monitoring wells, cone penetrometer borings, and exploratory trench locations completed during the Phase II fieldwork were surveyed for both horizontal and vertical coordinates. The elevations of the tops of the well casings were surveyed to the nearest 0.01 foot for all new monitoring wells, landfill gas probes, and vapor extraction/monitoring wells. A mark was placed on each casing indicating the location that was surveyed. Horizontal positions and ground surface elevations were surveyed to the nearest 0.1 foot.

All points were surveyed by a registered surveyor, referenced to the semi-permanent monuments set onsite during the Phase I field investigation, and tied to the State Plane Coordinate System, North American Datum (NAD) 1983/91, and the National Geodetic Vertical Datum, (NGVD) 1929. Location surveying results are provided in Appendix C.

2.2 SOIL CHEMISTRY

Soil samples were collected for chemical analyses during the installation of monitoring wells MW-23S, MW-24S, MW-25S, MW-26S, MW-27S, and MW-28S at the depths listed in Table 2.3. Samples were collected using steel split-spoon samplers. Borings MW-23S and MW-24S were installed on May 6, 1995. Samples for VOC and priority pollutant metals were collected at 40 feet below ground surface (bgs) from boring MW-23S and 50 feet bgs from MW-24S. Borings MW-27S and MW-28S were installed on May 30, 1995. Samples for metals and herbicides

were collected from 60 feet bgs in both MW-27S and MW-28S. A discussion of the soil sampling at MW-25S and MW-26S can be found in Section 2.11.3.

2.3 HYDROGEOLOGY

Five shallow onsite groundwater monitoring wells (MW-23S, MW-24S, MW-26S, MW-27S, and MW-28S), one shallow upgradient offsite groundwater well (MW-25S), and four shallow downgradient offsite groundwater monitoring wells (MW-29S, MW-30S, MW-31S, and MW-32S) were installed during May 1995. Based on subsequent groundwater sampling results, one additional onsite well and ten additional offsite wells were also installed. Onsite well MW-12ID was installed on December 4, 1995, to monitor groundwater contaminant levels in the intermediate zone. Three offsite wells were installed during October 1995 (MW-33S, MW-34S, and MW-35S), four during March 1996 (MW-36S, MW-37S, MW-38S, and MW-39S), and three in July 1996 (MW-40S, MW-41S, and MW-42S).

All wells installed as part of the Phase II RI field activities were completed with ten-foot lengths of 2-inch diameter, 0.01-inch wire-wrap stainless steel well screens attached to 2-inch-diameter stainless-steel risers extending a minimum of ten feet above the static water level in the borehole. A 2-foot stainless-steel sump was attached to the bottom of each well screen. All shallow wells were screened across the soil-groundwater interface. Intermediate depth well MW-12ID was completed with the top of the screen approximately 19 feet below the water table. All wells were completed to ground surface with 2-inch diameter PVC risers.

Completion details for groundwater monitoring wells at the site are provided in Table 2.4 and Table 2.5. Details concerning well construction and installation procedures are provided in Appendix A. Boring logs for all wells are contained in Appendix B. Offsite wells are shown in Figure 2-2. Onsite well locations are provided in Figure 2-3. Figure 2-4 provides a schematic illustration of typical monitoring well construction using well cluster MW-12 as an example.

A new dedicated 2-inch diameter submersible, high-capacity stainless-steel pump (Grundfos Redi-Flo 2) was used to develop each well. Each new well was developed by pumping the well until the discharge water was clear and the pH, specific conductivity, temperature, and turbidity of the discharge water had stabilized. The static water level at each well was measured and recorded prior to development. All wells were allowed to stabilize for a

minimum of five days prior to sampling. Additional details concerning well development procedures can be found in Appendix A.

Groundwater elevation measurements were collected quarterly from each well using an electronic water-level indicator prior to collection of groundwater samples. The indicator tip and cable of the water-level indicator were thoroughly decontaminated between wells in accordance with the procedures outlined in the SAP. All pertinent information and unusual conditions were recorded in the sampler's log book and recorded on the appropriate field forms.

In addition to quarterly measurements, continuous monitoring of groundwater elevations was conducted in three shallow groundwater monitoring wells (MW-10S, MW-23S, and MW-28S). MW-10S was equipped with a downhole pressure transducer and a barometric pressure transducer linked to a multi-channel data logger. Monitoring wells MW-23S, and MW-28S were equipped with downhole pressure transducers linked to single-channel data loggers. The data from the data loggers were downloaded quarterly to a laptop computer and returned to Philip's Seattle office for evaluation.

Continuous groundwater elevation monitoring was conducted at the three wells during two separate events. The first event extended from June 1995 through July 1996. The second event began in December 1996 and continued through June 1997.

2.4 GROUNDWATER CHEMISTRY

Each groundwater monitoring well has been equipped with a dedicated sampling pump to minimize the potential for cross-contamination between wells. Three types of sampling pumps are currently in use at the site; piston pumps, bladder pumps, and 2-inch diameter submersible pumps.

Wells #1, #2, and #3 were constructed with two screened sections. During the Phase II field work, inflatable packers were placed between the screened sections of these wells to isolate the upper screened interval for groundwater sampling.

The Phase II SAP stated that wells #4 and #5 would have inflatable packers installed. Well #4 was originally constructed with two screened sections. During the Phase II field work, it was discovered that the lower screened section had previously been abandoned with bentonite slurry. Therefore, installation of a packer was not possible. Well #5 was incorrectly identified

in the SAP as having two screened sections. Further investigation revealed that well #5 was constructed with a single screened section. Therefore, no packer was installed in well #5.

Prior to collection of groundwater samples, each well was purged using low flow techniques in accordance with procedures outlined in the current USEPA guidance (USEPA 1992). Groundwater was removed at a rate that did not exceed four liters per minute. The groundwater elevation in each well was measured and recorded before purging. Dissolved oxygen, pH, conductivity, temperature, and oxidation-reduction (redox) potential and pumping rate were measured and recorded continuously while purging the well, using an Accuwell 820 Controller connected to the discharge end of the pump. Turbidity readings were collected manually and recorded every two liters by the sampler.

Purging continued until dissolved oxygen, oxidation-reduction potential, and turbidity readings stabilized to within ten percent for two consecutive readings. The wells were then sampled without increasing the pump speed. Refer to Appendix A for a more complete discussion of purging and sampling methods. Purge water was drummed and staged onsite for disposal in accordance with the procedures specified in the SAP. Well purging data is provided in Appendix D.

Groundwater monitoring wells were sampled quarterly following the program summarized in Table 2.6. All sample collection, handling, and documentation procedures were conducted in accordance with the SAP. All analyses were performed on unfiltered samples. Duplicate and blank samples were collected and analyzed in accordance with the requirements specified in the SAP.

Ecology granted approval for a reduction in the ongoing quarterly groundwater monitoring program. A listing of the wells and analytes included in the Post Remedial Investigation Quarterly Groundwater Monitoring Program is provided in Table 2.7.

During the summer of 1995, it was determined that off-site groundwater had been impacted by releases from the site. This determination resulted in an increase in the scope of the Phase II RI to include an expanded off-site groundwater investigation and installation of an additional groundwater monitoring well hydraulically downgradient from the site between March 1996 and July 1996. To allow inclusion of sufficient data from the offsite wells, the monitoring period used for assessment of offsite groundwater was extended until June 1997. As

a result, the evaluation of groundwater chemistry presented in this report encompasses two distinct time periods. Groundwater data collected between June 1995 and July 1996 were used in characterization of groundwater contamination beneath the site. Data collected between October 1995 and June 1997 were used in characterization of offsite groundwater.

2.5 MUNICIPAL LANDFILL

2.5.1 LANDFILL GAS

Two landfill gas probe clusters (LFG-01, LFG-02) were installed along the western boundary of the Municipal Landfill during the Phase I RI field investigation. Two additional landfill gas probe clusters (LFG-03 and LFG-04) were installed along the southern boundary during the Phase II field investigation (Figure 2-5). Each cluster was completed by installing three individual 1-inch diameter PVC probes (shallow, intermediate, and deep) in a single 12-inch diameter boring, with the exception of LFG-02 which has two (11 total). Each probe was completed with a 5-foot length of 1-inch diameter, PVC, 0.01-inch mill-slotted well screens.

Soil samples were collected in split-spoon samplers at five-foot intervals to characterize the geology at each location. Depths of the screened intervals were determined in the field by the site geologist based on geologic conditions encountered during installation. Probe installation followed the guidelines in the Ecology Solid Waste Landfill Design Manual (WADOE #8713, 1987). Landfill gas probe construction details are provided in Table 2.8. Graphic representations are provided in Figure 2-6 through Figure 2-9. Additional details regarding the installation of the landfill gas probes can be found in Appendix A.

Landfill gas samples were collected quarterly from landfill gas probe clusters LFG-01, LFG-02, LFG-03, and LFG-04 during three Phase II field events. Monitoring parameters included oxygen, methane, percent lower explosive limit (LEL), hydrogen sulfide, hydrogen, carbon dioxide, and VOCs. Gas samples were collected after purging a minimum of one probe volume of air using a vacuum pump. During one field event, all LFG probes were under positive pressure and pumping was not required for purging prior to sample collection.

Oxygen and LEL concentrations were measured directly using a combustible gas indicator (CGI). Methane concentrations were determined indirectly by comparing the percent

LEL of the gas in the well to the LEL for methane and assuming that the concentration of other VOCs in the well was insignificant when compared to the total methane concentration. Methane concentrations were then calculated by multiplying the percent LEL measured in the probe by the LEL for methane (5.53 percent). The CGI was calibrated with ten percent LEL methane, 20.9 percent oxygen, and ten percent hydrogen sulfide gas prior to sample collection.

Problems with the CGI were experienced during the fourth quarter 1995 sampling event. As a result oxygen, LEL, and methane data were not obtained. Therefore, an additional landfill gas sampling event for these parameters was completed in March 1996.

Hydrogen, hydrogen sulfide, and carbon dioxide were measured using a Sensidyne gas sampling pump fitted with the appropriate analytical tubes. VOC samples were collected in tedlar bags, labeled, and shipped to an offsite laboratory for analysis using Method 8260. All sample collection, handling, labeling, and documentation was conducted in accordance with the procedures outlined in the SAP.

2.5.2 STRUCTURE MONITORING

Onsite structures, including the scale house, pump house, maintenance shop, and mobile home foundation, were monitored quarterly using a CGI to assess potential methane concentrations. No methane was detected in any onsite structure during any monitoring event.

2.5.3 GROUNDWATER CHEMISTRY, MUNICIPAL LANDFILL

Groundwater monitoring wells #3, #4, #5, #6, #8, #9, MW-15S, MW-16S, MW-17SR, MW-22S, MW-23S, and MW-24S were sampled quarterly to provide an assessment of the groundwater conditions associated with the Municipal Landfill (Figure 2-5). Groundwater monitoring well NW-5 was sampled quarterly to provide information on background conditions. Sampling of wells #3, #9, and MW-15S was discontinued as part of implementation of the ongoing monitoring program in June 1996.

2.6 ZONE E AND ZONE TS-1/SL-1

2.6.1 GEOPHYSICAL INVESTIGATION, ZONE E AND ZONE TS-1/SL-1

Electromagnetic (EM) induction is a surface geophysical technique used to measure terrain conductivity, which is the bulk electrical conductivity of subsurface materials. EM induction surveying is primarily employed as a method for mapping rapid lateral variations in soil conductivity.

Two types of EM conductivity instruments have been used as investigative tools at the Pasco Landfill, a Geonics EM-31 Terrain Conductivity Meter and a Geonics EM-34 Terrain Conductivity Meter. The EM-31, which was used at Zone TS1/SL-1, uses a transmitter coil to radiate a continuous electromagnetic field and induce circular electrical currents (eddy currents) in the earth below the coil which then generates a secondary magnetic field. Signals from both the primary field and the secondary magnetic field are collected by a receiver coil and transmitted back to the conductivity meter which converts the ratio of the two magnetic fields to provide an indication of the apparent conductivity (terrain conductivity) of the subsurface. The terrain conductivity measurement represents a weighted summation of subsurface conductivity from the ground surface to the effective depth of exploration of the instrument (about 20 feet for the EM-31).

In addition to its primary use in the measurement of lateral variations in subsurface conductivity, the EM-31 also has application in the search for buried metallic objects. By including a digital electronic notebook (an Omnidata Polycorder) in the EM-31 field system, it is possible to record both the quadrature phase of the secondary magnetic field as well as the portion of the field aligned in-phase with the primary transmitted field. The quadrature phase of the secondary magnetic field contains the conductivity information while the in-phase portion is an effective indicator of the presence of buried metallic objects.

A ground magnetics survey was also completed at Zone TS-1/SL-1. The magnetic survey method is based on the detection of contrasts in the magnetization of subsurface materials by passive surface measurements of the earth's magnetic field. The magnetic method has application in the search for naturally occurring concentrations of magnetic minerals, as well as buried man-made ferromagnetic (iron and steel) objects.

EM-31 and ground magnetics surveys were conducted over Zone TS-1/SL-1 during the Phase II field investigation to assess the area for the presence of buried metallic waste (Figure 2-10). The initial task for both surveys consisted of re-establishing the Phase I survey grid to allow correlation of Phase I and II data using the same coordinate system. The Phase I grid was then expanded to meet the objectives of the Phase II investigation. During the EM-31 survey, both quadrature and in-phase conductivity data were collected at 10-foot intervals along profiles with 20-foot spacings. The ground magnetics survey was conducted using a GeoMetrics G856 Magnetic Gradiometer at intervals of ten feet along the pre-established geophysical profiles spaced ten feet apart. Both total magnetic field and vertical magnetic gradient measurements were collected at each data station and transferred to a computer for evaluation.

In addition to their use as investigative tools, both EM-31 and ground magnetics were used to clear all potential drilling or intrusive investigation locations. The clearance survey involved the collection of both EM and magnetic measurements along two perpendicular profiles centered on the proposed locations. A detailed description of the methodology and results of the Phase II RI/FS geophysical investigation is contained in the Northwest Geophysical Associates (NGA) Geophysical Survey Report and is included as Appendix E of this document.

2.6.2 BULK WASTE CHARACTERIZATION STUDY, ZONE E

In accordance with the Phase II RI/FS Work Plan, samples of the material contained in Zone E were collected for observation and analysis. The objectives of these analyses were to aid in the determination of ARARs and to provide information regarding whether the material poses a threat to human health or the environment. To make this determination, the construction of the zone was observed and the nature of the soil cover and cap overlying the material was documented. Waste profiling analyses were completed on the samples to characterize the material.

Direct observation and sampling of the material at Zone E was performed by excavating a trench into the material using a trackhoe (Figure 2-10). Field observation and sampling of the material in Zone E was completed on May 22, 1995. During excavation, Zone E was observed to be capped with a vegetated soil cover approximately three-feet thick. A trench the width of the trackhoe bucket was excavated to the top of the plastic liner overlying the material. The

plastic liner was then removed using the trackhoe, and the trench was excavated in layers to a total depth of approximately 9 feet.

Excavated soil and material were segregated and stockpiled on plastic sheeting within the boundary of Zone E. The depth to the plastic cap and the thickness and nature of the material were logged, and the trench was photographed. During all intrusive activities, air quality (LEL, hydrogen sulfide, oxygen, and total VOCs) was monitored continuously. All work was completed with Level D personal protective equipment (PPE) requirements.

Silty sand was observed overlying a plastic liner at a depth of approximately 3 feet bgs. Material was encountered immediately underlying the plastic liner and extending to the bottom of the trench (approximately 9 feet bgs). No soil was observed at the bottom of the excavation, indicating that material at this location extended below 9 feet bgs. Samples of material were collected from various depths in the trench, composited in a five-gallon container, and submitted to the analytical laboratory for analysis. Waste profiling analyses were performed using multiple sample composites. Following sample collection, the trenches were backfilled with material, covered with bentonite, and capped with clean stockpiled soil. Sample collection, handling, custody, and shipping procedures adhered to the SAP.

In addition to the May 1995 trenching activities, six discrete waste samples were collected from Zone E on May 9, 1997 to evaluate the material as a potential source of VOCs and chromium in groundwater. Three samples were collected from the north cell, and three samples were collected from the south cell of Zone E (Figure 2-10). All samples were collected from approximately six feet below the current ground surface (approximately three feet below the plastic liner). The samples were collected using a pre-cleaned stainless-steel hand-auger. Each sample was submitted to the laboratory and analyzed for VOCs, total chromium and hexavalent chromium. In addition, one composite sample was collected from each cell (north and south) for analysis of leachable VOCs using TCLP methodology. Composite samples were collected by placing a small portion from the three discrete samples in each of the two Zone E cells, into a stainless-steel bowl, mixing thoroughly, then placing the waste mixture into a sample container. Following sample collection, each boring was backfilled with bentonite clay.

2.6.3 SOIL CHEMISTRY, ZONE E AND ZONE TS-1/SL-1

The results of the Phase II EM-31 survey revealed the presence of a low-amplitude conductivity anomaly in the former SL-1 Lagoon Overflow area adjacent to Zone TS-1/SL-1 (Section 3.61). The ground magnetics survey of the area did not indicate the presence of buried metallic objects that might explain the anomaly; however, elevated chromium concentrations have been detected in groundwater samples collected from EE-8 and MW-19S downgradient from Zone TS-1/SL-1. As a result, two soil borings (B-17 and B-18) were installed to assess the conductivity anomaly as a potential source of chromium in groundwater (Figure 2-10).

Borings B-17 and B-18 were installed within the anomaly on April 3, 1996, using a 4.25-inch diameter hollow-stem auger. Each soil boring was sampled continuously from ground surface to a total depth of approximately 20 feet bgs using 2.5-inch diameter stainless-steel split-spoon samplers. Soil samples were collected from 5, 10, 15, and 20 feet bgs and submitted for hexavalent and total chromium analyses. One duplicate sample was collected from boring B-17 at 15 feet bgs. All samples were collected in accordance with the procedures contained in the SAP. Boring logs are included in Appendix B.

2.6.4 GROUNDWATER CHEMISTRY, ZONE E AND ZONE TS-1/SL-1

Three wells (EE-8, MW-19S, and MW-27S) have been designated as Zone E Monitoring Wells for the purpose of assessing potential impacts to groundwater associated with Zone E and TS1/SL1. Well #9 is the closest Landfill Well to Zone E and is known to capture groundwater emanating from the east side of the former Municipal Landfill. For this reason, well #9 was used to provide data for characterization of the chemical composition of groundwater from the former Municipal Landfill and to assess the potential for hydraulic transport of contaminants from the northeastern portion of the former Municipal Landfill to the groundwater beneath Zone E.

The site history presented in the Phase I RI Report (Burlington Environmental, 1994) indicates that chlor-alkali process waste was placed in Zone E. In addition, the results of waste analyzed from Zone E indicated the presence of elevated levels of mercury. As a result, groundwater samples collected from monitoring wells EE-8, #9, MW-19S, MW-20S, and MW-27S were analyzed for mercury during the March 1996 sampling event.

As discussed in Section 3.6.1, below, an apparent conductivity anomaly was observed in the EM-31 survey data collected from the central portion of Zone TS-1/SL-1. In addition, historical groundwater sampling results indicated elevated levels of chromium in monitoring wells EE-8 and MW-19S to the southwest, hydraulically downgradient from this location (Figure 2-10). As a result, wells EE-8 and MW-19S were analyzed for hexavalent and total chromium during March 1996.

2.7 ZONES C AND D

2.7.1 GEOPHYSICAL INVESTIGATION, ZONES C AND D

Deep reconnaissance electromagnetic surveys were conducted over Zones C and D using a Geonics EM-34 terrain conductivity meter during the Phase II field investigation. The objective of this work was to assess the areas for the presence of anomalous soil conductivities at depth. The EM-34 operates on the same principle of electromagnetic induction as the EM-31 unit described in Section 2.6.1 above. However, in the EM-31 instrument, the transmitting and receiving coils are mounted at the ends of a 3.7-meter grid boom and can be operated by one person. The EM-34 requires two operators, but achieves greater exploration depth by allowing greater separation of the transmitting and receiving antennae (10, 20, or 40 meters) and by operating at successively lower frequencies at larger coil separations. At the largest coil separation (40 meters), an exploration depth in excess of 100 feet can be attained.

The Geonics EM-34 Terrain Conductivity Meter uses the in-phase portion of the secondary magnetic field to correct for varying coil separation lengths. Thus, the in-phase portion of the signal is not available for recovery. Because in-phase data are normally applied to detection of buried metallic objects, this did not present a problem with respect to the Phase II objectives which focused on evaluation of potential anomalous soil conductivities at depth. Soil conductivity data are contained within the quadrature portion of the signal, and are fully available for recovery.

An EM-34 reconnaissance survey was conducted over Zones C and D (Figure 2-11) to assess the areas for evidence of anomalous soil conductivities at depth, which might be indicative of a release. EM-34 measurements were collected over the disposal cells along with

background readings from outside the zones after first re-establishing the Phase I geophysical survey grids and expanding them to meet the Phase II objectives. All EM-34 field data were recorded on an Omnidata Polycorder and transferred to a computer for processing. A detailed description of the methodology and results of the Phase II RI/FS geophysical investigation is contained in the Northwest Geophysical Associates (NGA) Geophysical Survey Report and is included as Appendix E of this document.

2.7.2 BULK WASTE CHARACTERIZATION STUDY, ZONES C AND D

As with Zone E, direct observation and sampling of the material at Zones C and D was performed during the Phase II field work by excavating trenches into the material using a trackhoe (Figure 2-11). Field observation and sampling of the material in Zone D was completed on May 22, 1995. Zone C observation and sampling was completed on May 23, 1995. During excavation, both zones were observed to be capped with vegetated soil covers approximately three feet thick. At each zone, a trench the width of the trackhoe bucket was excavated to the top of the plastic liner overlying the material. The plastic liner was then removed using the trackhoe, and the trench was excavated in layers to a total depth of approximately 9 feet bgs.

Excavated soil and material were segregated and stockpiled on plastic sheeting within the boundary of the zones. The depth to the plastic liner and the thickness and nature of the material in each trench were logged, and each trench was photographed. Air quality (LEL, hydrogen sulfide, oxygen, and total VOCs) was monitored continuously during all intrusive activities. Exceedances in air monitoring parameters at both zones resulted in Level C PPE requirements for personnel within the exclusion zone.

During trenching at Zone C, silt and sand were encountered to a depth of approximately 3 feet, where a plastic liner was observed. Material was encountered immediately underlying the plastic liner. Soil was encountered at about 6 feet bgs in Zone C, indicating the thickness of waste in this location is approximately 3 feet. Samples of material were collected from various depths in the trench and composited in a five-gallon container. Waste profiling analyses were performed using multiple sample composites. A soil sample was collected from beneath the waste at a depth of approximately 6 feet bgs.

Trenching at Zone D revealed sand and silt to a depth of approximately 3 feet bgs where a plastic liner was encountered. Material was observed immediately below the liner and extending to the bottom of the excavation at approximately 9 feet bgs. A subsequent soil boring completed through Zone D also revealed material extending to approximately 9 feet bgs. Samples of material were collected from various depths in the trench and composited in a five-gallon container. Waste profiling analyses were performed using multiple sample composites. Following sample collection, the trenches were backfilled with the excavated material, covered with bentonite, and capped with clean stockpiled soil. Sample collection, handling, custody, and shipping procedures adhered to the SAP (Burlington Environmental Inc., 1995b)

2.7.3 SOIL CHEMISTRY, ZONES C AND D

Two soil borings (B-19 and B-20) were installed on May 15 and 16, 1996, during the Phase II field investigation, to assess the soil beneath Zones C and D for the presence of VOCs and potential impacts to groundwater. Soil boring B-19 was advanced through Zone D; B-20 was advanced through Zone C (Figure 2-11). Each boring was installed at the approximate center of the zone. On May 15, 10.25-inch inside-diameter hollow-stem augers were advanced through the waste into the underlying soil at each location. Samples were collected from 11 feet bgs at Zone C and 14 feet bgs at Zone D. A 15-foot length of 9-inch-diameter, carbon-steel surface casing was then installed through the augers to a depth of 14 feet bgs in each zone, grouted in place, and the augers removed.

After allowing the grout to set up overnight, each boring was advanced through the surface casing to a total depth of 60 feet bgs using 4.25-inch hollow-stem augers. The first soil sample was collected at approximately 16 feet bgs, just below the base of the steel casing. Thereafter, split-spoon samples were collected every 10 feet, with the final sample collected at 60 feet bgs. Each sample was submitted for VOC analysis by Method 8260.

Soil and waste cuttings from each boring were segregated, drummed, and staged onsite for disposal. Composite samples of both soil and waste were collected from each boring and submitted for waste profiling analyses to assess potential disposal options for the drummed cuttings. Boring logs are included in Appendix B.

After collecting the final sample, each boring was abandoned by grouting from the bottom of the hole to the surface using bentonite grout in accordance with the requirements of Chapter 173-160 WAC. Grout was tremied through the augers to the bottom of the borings. After the grout had filled the augers, the augers were removed from the boring one section at a time, keeping the augers full of grout to maintain positive pressure. Once all sections of augers had been removed, the steel casing was pulled, and the remainder of the boring was grouted to ground surface. The location of each boring was surveyed by a licensed surveyor upon completion.

2.7.4 GROUNDWATER CHEMISTRY, ZONES C AND D

Wells EE-6, EE-7, and MW-18S were designated as Zone C and D Monitoring Wells and were used for assessing groundwater conditions in the vicinity of Zones C and D (Figure 2-11). Wells #8 and #9 were used to provide data for use in characterizing the chemical composition of groundwater down gradient from the former Municipal Landfill and assessing the potential for hydraulic transport of contaminants from the former Municipal Landfill as a source of VOCs in groundwater beneath Zones C and D. Data from wells MW-28S and NW-5 were evaluated to assess contaminants in background wells upgradient from Zone C and D.

2.8 LAGOONS SL-2 AND SL-3

These areas were adequately characterized in the Phase I RI. No Phase II investigation activities were specified by the Enforcement Order.

2.9 ZONES U-1 AND TS-2

Zones U-1 and TS-2 were adequately characterized in the Phase I RI. As a result, no Phase II investigation activities were specified in the Scope of Work contained in the Enforcement Order for the site. The results of the Phase I investigation are contained in Section 5.1.5 of the Phase I RI report.

2.10 SLUDGE MANAGEMENT AREA AND LANDSPREAD AREA

These areas were adequately characterized in the Phase I RI. No Phase II additional investigation activities were specified in the Scope of Work contained in the Enforcement Order. The results of the Phase I RI investigation of the Sludge Management and Landspread Areas are contained in Section 5.2 of the Phase I RI report.

2.11 ZONE B

2.11.1 GEOPHYSICAL INVESTIGATION, ZONE B

Ground Penetrating Radar (GPR) is a surface geophysical technique that employs the principles of radar transmission and reflection to generate a continuous graphical profile of subsurface conditions. GPR surveys were conducted during the Phase II field work using a Geophysical Survey Systems Inc. (GSSI) Model SIR-3 GPR system. The GSSI system consists of an instrument console and graphical recorder, a sled-mounted transmit/receive antenna, and a transducer control cable which connects the antenna to the processing equipment.

During a GPR survey, the GPR antenna is towed along a transect line, and the reflected GPR signals are displayed on the graphical recorder as a vertical, two-dimensional continuous profile along the line of traverse. The graphical display (radargram) is somewhat analogous to a geologic cross-section, although the subsurface soil interfaces and/or buried objects are displayed in terms of two-way (reflection) travel time rather than depth. The measured reflection times can then be converted to depth by calibrating the instrument using known depths to target materials.

The objective of the GPR survey program was to profile the thickness of soil cover overlying the drums buried in Zones A and B and check for areas of subsidence which may provide evidence that the drums have corroded, collapsed, or are generally in poor condition. The soil cover thickness overlying the drums was expected to range between 3 and 6 feet. A 300-MHz antenna, designed for investigation depths ranging between 3 and 30 feet, was selected for the Phase II investigation with a 500-MHz antenna mobilized to the site as a backup.

The GPR survey was completed at Zone B on April 26, 1995 (Figure 2-12). Before initiating the survey, the GPR was calibrated to both native *in-situ* and native backfilled soil.

The survey locations were based on existing grids constructed during previous geophysical studies. Each survey was completed using 300-MHz and 500-MHz antennas. A detailed description of the methodology and results of the Phase II RI/FS geophysical investigation is contained in the NGA Geophysical Survey Report and is included as Appendix E of this document.

2.11.2 DRUMMED WASTE CHARACTERIZATION STUDY, ZONE B

The Enforcement Order for the site requires completion of a Drummed Waste Characterization Study in Zones A and B. As specified in the order, the objectives of the study included:

- assessment of the nature, integrity, and composition of the cover;
- assessment of the vapor-phase chemical composition of soil-gas surrounding the zone;
- assessment of the physical condition of the drums through direct observation; and
- assessment of the chemical composition and physical state of the containerized wastes.

Although one of the stated objectives of the study was to assess the physical condition of the drums through direct observation, Ecology and the PLP Group agreed on a phased approach that meets the general objectives of the study, while minimizing the potential for risk to human health or the environment associated with intrusive investigative approaches. This phased approach was outlined in the Phase II RI/FS Work Plan and uses non-intrusive investigative techniques including GPR, EM, resistivity, and self-potential surveys, as well as soil-gas sampling and analysis. The phased approach involved the assessment of:

- drum and cover conditions;
- the likelihood of biodegradation occurring within the drummed waste;
- the likelihood of past releases;
- expected corrosion rates of the drums from soil conditions and waste characteristics;
- the potential for hazardous working conditions or releases of wastes if the drums were exposed during future study; and
- the extent to which the objectives of the study have been met for the purpose of supporting the Feasibility Study.

The data generated by the non-intrusive drummed waste characterization task were then evaluated using criteria specified in the Work Plan to assess if intrusive tasks are feasible and can be completed without unreasonable risk to human health or the environment. This evaluation included the following considerations:

1. If data from the non-intrusive tasks indicate that the drums have deteriorated significantly, characterization of the drummed waste through intrusive fieldwork would not be considered feasible because neither direct observation (e.g., observation of labels or other markings) or sampling of drum contents would be possible.
2. If data from the non-intrusive tasks indicate corrosive or anoxic (oxygen-deficient) conditions surrounding the drums, intrusive fieldwork would not be considered feasible because of the potential to result in excessive risks to the environment by adversely affecting drum integrity through the introduction of oxygen. Additionally, if the drums are determined to be in poor condition, removal of surrounding soil could result in catastrophic failure of exposed drums potentially resulting in a commingling of incompatible wastes, thereby creating heat, fire, or explosion hazards which could cause further releases.
3. Either of the conditions described above would also present serious potential health and safety concerns due to risks associated with fire, explosion, or the sudden release of hazardous substances resulting from drum failure.

2.11.2.1 GEOPHYSICAL SURVEYS

A GPR survey was conducted at Zone B in an attempt to profile the thickness of soil cover overlying the drums and check for areas of subsidence which may provide evidence that the drums have corroded, collapsed, or are generally in poor condition.

2.11.2.2 SOIL-GAS SURVEY

Soil-gas samples were collected from the area adjacent to Zone B and analyzed for oxygen, carbon dioxide, methane, and acid-gas concentrations to provide evidence of biodegradation, anoxic, and/or corrosive conditions. Low oxygen concentrations, elevated carbon dioxide concentrations, and the presence of methane are indicators of anoxic conditions and biodegradation. The presence of acidic vapor is an indicator of a corrosive environment. Evidence of biodegradation and anoxic conditions may suggest that a release from buried drums

has occurred, while a corrosive environment would suggest a shortened life expectancy for the drums and/or a possible release of acidic waste from the drums.

Each sample was collected by advancing a 1-inch outside-diameter steel probe rod fitted with an expendable stainless-steel drive point into the ground to the desired sampling depth. Once the sampling depth was reached, the probe was retracted approximately 0.5 foot to separate the expendable tip from the probe rod and create a void from which to collect the vapor sample. Soil-gas samples were obtained by fitting the aboveground end of the probe rod with an air-tight cap attached to a length of single-use tubing leading to a vacuum pump.

Approximately four liters of soil-gas were evacuated from the borehole prior to sampling each interval. Soil-gas samples were then collected in tedlar bags through the use of a 3-way valve on the sample collection tubing. Soil-gas samples from the tedlar bags were then analyzed for oxygen and methane using a CGI, and for carbon dioxide and acid-gas using a Sensidyne gas sampling pump fitted with the appropriate analytical tubes.

Soil-gas samples were collected from eight locations surrounding Zone B on May 1, 1995 (Figure 2-12). Samples were collected at depths of 5, 15, and 21 feet bgs from locations PH-28, PH-29, and PH-35 and from 5, 10, and 15 feet bgs from probeholes PH-30, PH-31, PH-32, PH-33, and PH-34.

2.11.2.3 CORROSIVITY SURVEY

A soil corrosivity survey was completed by Corrosion Control Specialists (CCS) at Zones A and B on June 6, 1995, using methods commonly employed for the design of cathodic protection for buried pipelines and underground storage tanks. Data from the CCS survey were used to assess the corrosivity of soil surrounding the two zones and estimate the life expectancy of the buried drums. The corrosivity survey contained the following elements:

- laboratory analysis of sulfide, moisture content, pH, conductivity, resistivity, and saturated resistivity at each zone;
- *in-situ* soil resistivity testing;
- generation of a corrosion index from *in-situ* and laboratory data using a computer model; and
- an estimation of potential corrosion damage to the insides of the drums by assessing the types of wastes stored in the drums.

Soil resistivity is considered to be the soil property that most influences soil corrosivity (Table 2.9). Therefore, the main focus of the survey was generation of *in-situ* and laboratory soil resistivity data. Soil samples were submitted for laboratory analyses from four locations (MW-26S, B-13, B-14, and B-15) near Zone B (Figure 2-12).

In-situ resistivity testing was completed at three locations near Zone B (Figure 2-13). Testing was completed using the Wenner four-electrode method outlined in ASTM G57-78. The Wenner method measures the average resistivity of the soil corresponding to the spacing of the four electrodes driven into the ground. Target exploration depths for the study were 2.5, 5, 7.5, 10, 20, and 30 feet bgs.

A computer corrosivity model developed by CCS was used to generate a relative corrosivity index for the soil from the resistivity data. The corrosivity index is a non-dimensional number ranging between 0 and 100. An index of 1 indicates a corrosion rate near 0, while an index of 99 indicates a pitting rate of one quarter of an inch or more per year. Additional information regarding the corrosivity survey is provided in Appendix F of this report.

2.11.2.4 SELF POTENTIAL SURVEY

A self potential (SP) survey was also completed over Zones A and B to provide additional data concerning the rates and degree of corrosion associated with the drums buried in these two areas. SP is used to measure differences in potential between electrical fields generated by electrochemical, electrokinetic, and thermoelectric processes occurring within the earth. The corrosion of buried steel objects generates a potential field. In addition, if the drums have corroded and leaked fluids, electrochemical anomalies may be generated by diffusion gradients between fluids of different compositions.

The SP survey was completed at Zone B on May 31, and June 1, 1996, by ERM-Rocky Mountain, Inc. (ERM) using the existing 10-foot geophysical survey grid at each location. Measurements were collected using nonpolarizable electrodes and a digital multimeter. At each location, a reference electrode was placed away from the survey grid in an area thought to be free from electrical interference. A second, roving electrode was then used to collect measurements of the potential difference at each survey location. The roving electrode was returned to the location of the reference electrode every hour to correct for electrode drift.

Based on the assumption that a drum at the site would corrode completely in 20 years, ERM calculated that a single drum corroding at this rate would generate an SP anomaly of approximately 260 millivolts. Although this calculation is based on simplified assumptions, it provides a guideline for comparison with the survey results. A more complete discussion of the SP method is provided in Appendix G of this report.

2.11.3 SOIL CHEMISTRY, ZONE B

According to historical records, the waste materials present in Zone B include approximately 5,000 drums of 2,4,-D tar and MCPA-bleed derived from the herbicide-manufacturing process. Because dioxins are known to occur as contaminants in herbicide wastes, a comparison between herbicide and dioxin concentrations in background and subsurface soil samples collected from Zone B was conducted as part of the Phase II field investigation to assess whether a release of these compounds from the drummed wastes present in Zone B has occurred. The scope of work included in this task consisted of the following:

- collection and analysis of background samples for herbicides and dioxins to establish site background concentrations;
- assessment of herbicide and dioxin concentrations in soil samples collected from the area surrounding Zone B;
- a statistical comparison between site background concentrations and the concentrations of dioxins in Zone B soil; and
- a comparison between dioxin concentrations in the soil surrounding Zone B and MTCA Method B formula values.

Area Background Soils. A total of 16 surface soil samples and 4 subsurface soil samples (20 total) were collected and analyzed for herbicides and dioxins to establish site background concentrations. Surface soil samples were collected from an offsite background sampling grid established in the agricultural field situated to the east of Zone B (Figure 2-12). All surface soil samples were collected on April 27, 1995, from a depth of 0.5 feet bgs. Subsurface soil samples were collected from depths of 10, 20, 30, and 40 feet bgs on May 1, 1995, during installation of offsite groundwater monitoring well MW-25S. Subsurface soil samples collected from MW-25S were included with surface soil samples to calculate site

background values. A summary of background sampling locations, dates, and depths can be found in Table 2.10.

Zone B Soil. A total of 16 subsurface soil samples were collected on May 1, 1995, from four soil borings installed in the area surrounding Zone B. One of the borings was completed as groundwater monitoring well MW-26S. Table 2.11 provides a listing of subsurface soil samples collected from the area adjacent to Zone B. All sample collection, storage, transportation, analytical, and documentation procedures were consistent with the protocol outlined in the SAP.

2.11.4 GROUNDWATER CHEMISTRY, ZONE B

Three groundwater monitoring wells (EE-4, EE-5, and MW-26S) have been designated as Zone B Monitoring Wells for the purpose of assessing potential impacts to groundwater associated with Zone B. Additionally, groundwater monitoring well MW-25S was used to provide upgradient and background data.

2.12 ZONE A/NORTH-SOUTH BURN TRENCH/BALEFILL

2.12.1 GEOPHYSICAL INVESTIGATION, ZONE A/NORTH-SOUTH BURN TRENCH

Ground magnetics surveys were employed during Phase II to evaluate the area for evidence of buried metallic debris and assist in definition of the North-South Burn Trench. To allow correlation of Phase I and II data, the initial task consisted of re-establishing the Phase I geophysical survey grid for Zone A. This grid was then expanded to encompass the area of randomly disposed drums in Zone A and the reported location of the North-South Burn Trench (Figure 2-14). A magnetic survey was then conducted over the expanded grid to evaluate the signature of the North-South Burn Trench in relation to Zone A. The magnetics survey was conducted using a GeoMetrics G856 Magnetic Gradiometer at intervals of ten feet along the pre-established geophysical profiles with ten-foot spacings. Both total magnetic field and vertical magnetic gradient measurements were collected at each data station and transferred to a computer for evaluation.

EM-31 was used as a complementary investigative method along with ground magnetics at the North-South Burn Trench to aid in delineation of the burned waste area. As with the

magnetics survey, this involved re-establishing the Phase I geophysical survey grids and then expanding the grid to encompass the area of randomly disposed drums and the reported location of the North-South Burn Trench. EM-31 data were then collected at 10-foot intervals along profiles with 10-foot spacings.

An EM-34 reconnaissance survey was conducted over Zone A in an attempt to assess the apparent conductivity of soil at depth beneath the zone for indications of a potential release. After re-establishing the Phase I geophysical survey grid for Zone A, EM-34 measurements were collected over the Zone as well as background readings from outside the zone. Both horizontal and vertical dipole readings were collected at 25-foot intervals along pre-established survey lines with 50-foot spacings using 10-, 20-, and 40-meter coil separations.

A GPR survey was completed at Zone A on May 12, 1995, in an attempt to profile the thickness of soil cover overlying the buried drums and check for areas of subsidence which may provide evidence that the drums have corroded, collapsed, or are generally in poor condition. The survey was conducted in the same manner as the Zone B GPR survey discussed in Section 2.11.1 above. A detailed description of the methods and results of the Phase II RI/FS geophysical investigation is contained in the NGA Geophysical Survey Report and is included as Appendix E of this document.

2.12.2 DRUMMED WASTE CHARACTERIZATION STUDY, ZONE A

The Enforcement Order for the site requires completion of a Drummed Waste Characterization Study in Zones A and B. As discussed in Section 2.11.2 above, Ecology and the PLP Group agreed on a phased approach that meets the general objectives of the study, while minimizing the potential for risk to human health or the environment associated with intrusive investigative approaches.

2.12.2.1 GEOPHYSICAL SURVEYS

Data gathered from the overall geophysical program at the site were used to assess the condition of drums in Zone A indirectly. A GPR survey was conducted at Zone A in an attempt to profile the thickness of soil cover overlying the drums and check for areas of subsidence

which may provide evidence that the drums have corroded, collapsed, or are generally in poor condition. An EM-34 survey was also completed at Zone A to assess the apparent conductivity of soils at depth for evidence of past releases. This information would serve as an indication that the drums are in poor condition. A complete description of the GPR and EM-34 surveys at Zones A are provided in Sections 2.12.1 above.

2.12.2.2 SOIL-GAS SURVEY

As discussed in Section 2.11.2.2, a soil-gas survey was used to gather data for the non-intrusive Drummed Waste Characterization Study. Soil-gas samples collected from five locations surrounding Zone A between May 2 and May 7, 1996, were also part of the Soil Vapor Extraction Treatability Study (Figure 2-14). Samples were collected at depths of 10, 20, and 30 feet bgs from probeholes PH-36, PH-37, and PH-38, from 15 feet bgs at probeholes PH-39 and PH-41, and from 19 feet bgs at probehole PH-40. Probeholes PH-36, PH-37, and PH-38 were completed as vapor monitoring probes for use as part of the SVE treatability study monitoring network. Soil-gas samples were analyzed in the field for oxygen and methane using a CGI, and for carbon dioxide and acid-gas using a Sensidyne gas sampling pump fitted with the appropriate analytical tubes. Soil-gas samples from Zone A were also analyzed for VOCs to provide additional data concerning the extent of VOC contamination in the vadose zone. VOC samples were analyzed in the field using a mobile gas chromatograph (GC). Two additional samples were collected from probeholes PH-36 and PH-39 and submitted for VOC analysis at an offsite laboratory.

2.12.2.3 CORROSIVITY SURVEY

A soil corrosivity survey was completed at Zone A on June 6, 1995 by Corrosion Control Specialists (CCS). As discussed in Section 2.11.2.3, data from the CCS survey were used to assess the corrosivity of soil surrounding the zone and estimate the life expectancy of the buried drums, as well as to assess the corrosivity of the waste present in the drums. *In-situ* resistivity testing was completed at seven locations near Zone A (Figure 2-15). Target exploration depths for the resistivity survey were 2.5, 5, 7.5, 10, 20, and 30 feet bgs. Soil samples were submitted

for laboratory resistivity analyses from three locations near Zone A (VEW-01, VEW-02, and VEW-03; Figure 2-14).

2.12.2.4 SELF POTENTIAL SURVEY

As discussed in Section 2.11.2.4, an SP survey was completed over Zone A to provide additional data concerning the rates and degree of corrosion associated with the drums buried in this zone. The SP survey was completed at Zone A between June 1 and June 3, 1996, by ERM. A more complete discussion of the SP method is provided in Appendix G of this report.

2.12.3 SOIL CHEMISTRY, ZONE A

Based on the results of the Phase I RI, no soil samples were collected for chemical analyses from Zone A, the North-South Burn Trench, or the Balefill during the Phase II investigation activities.

2.12.4 SOIL-GAS, ZONE A

As discussed in Section 2.12.2.2 above, a soil-gas survey was completed at Zone A. As part of the Drummed Waste Characterization Study, soil-gas concentrations of oxygen, methane, carbon dioxide, and acid-gas were examined. Vertical variations in VOC concentrations in soil-gas were investigated as part of the baseline soil-gas survey completed at Zone A during the Soil Vapor Extraction Treatability Study.

2.12.5 GROUNDWATER CHEMISTRY, ZONE A

A time series analysis was conducted in groundwater monitoring wells EE-2 and EE-3 (Figure 2-14) on May 31, 1995, as part of the Phase II RI field investigation. The purpose of this study was to assess the potential for these two wells to act as conduits for downward migration of contaminants to groundwater from Zone A. Due to the relatively high concentrations of contaminants detected in these wells, their close proximity to Zone A, and the Phase I geophysical survey results, it is possible that one or both of the wells were installed through waste. It was proposed in the SAP that, if the two wells are acting as conduits for

downward migration of contaminants, water quality should improve as water is purged from the well, and should continue to improve as purging progresses.

The time series analysis was conducted on May 31, 1995. An initial sample was collected from the first purge water extracted from each well. There after one sample was collected for every five well volumes purged. A total of seven samples, (30 well volumes), were collected from each well. Although a target purge rate of 2 gallons per minute (gpm) was proposed, the poor condition of the dedicated Hydrostar piston pumps in these wells limited actual purge rates to approximately 1.7 gpm at EE-3, and 1 gpm at EE-2.

Each sample was analyzed for an abbreviated list of volatile organics, semivolatile organics, and metals (Table 2.12). Field parameters, including pH, specific conductance, turbidity, and temperature, were measured once for every five well volumes purged.

Ten wells (#1, #2, EE-2, EE-3, MW-10S, MW-11S, MW-12S, MW-12I, MW-12ID, and MW-13S) have been designated as Zone A Wells for the purpose of providing an assessment of groundwater conditions in the vicinity of Zone A (Figure 2-14). Three additional wells were used to assess groundwater upgradient from Zone A. Well MW-14S is located hydraulically upgradient from Zone A. Wells #3 and MW-18S provide monitoring points to assess groundwater quality between the Municipal Landfill and Zone A.

2.13 OFFSITE GROUNDWATER

A cone penetrometer investigation was conducted hydraulically downgradient from the site between May 1 and May 8, 1995, as part of the Phase II field investigation. The objective of this work was to gather preliminary groundwater quality data for use in optimizing the placement of offsite groundwater monitoring wells. The cone penetrometer investigation consisted of collecting of groundwater samples from 11 locations (Figure 2-16) hydraulically downgradient from the site. Groundwater samples from each location were screened onsite for VOC concentrations using a mobile gas chromatograph (Table 2.13). Two confirmatory samples were submitted for VOC analysis (Method 8260) in an offsite laboratory for comparison with the field screening results.

Four shallow offsite groundwater monitoring wells (MW-29S, MW-30S, MW-31S, and MW-32S) were installed during May 1995 and sampled for the list of parameters

shown in Table 2.6 to assess the nature and extent of offsite groundwater contamination. Based on groundwater sampling results from these four wells and subsequent sampling events, ten additional offsite wells were installed. Three wells (MW-33S, MW-34S, and MW-35S) were installed during October 1995, four (MW-36S, MW-37S, MW-38S, and MW-39S) during April 1996, and three (MW-40S, MW-41S, and MW-42S) in July 1996.

Wells MW-30S, MW-31S, and MW-34S were removed from the groundwater sampling program during July 1996 as part of the ongoing monitoring program for the site. Wells MW-35S and MW-39S were abandoned in September 1996 to allow construction of a new interchange at the intersection of Dietrich Road and Route 12.

3 RESULTS

This section summarizes the results of the Phase I and II RI activities conducted at the Pasco Landfill site. The discussion consists of a general presentation of sitewide geologic and hydrogeologic data and soil and groundwater chemistry, followed by a discussion of the investigation results organized by individual waste management zones.

3.1 GEOLOGY

The Pasco Landfill site is located within the Pasco Basin Geologic province of the Columbia River Plateau. The site is underlain by a thick sequence of basalts that are covered by a relatively thin sequence of semi-consolidated and unconsolidated sediments. Stratigraphic units beneath the Pasco Landfill site include the Columbia River Basalt Group (Yakima Basalt Subgroup), the Ringold Formation, the Hanford Formation (Pasco Gravels and Touchet beds), and eolian sands and silts. This sequence is very similar to the regional stratigraphy (Section 1.2.3), the key difference being the lack of the Upper Ringold Formation and Palouse silts and sands at the site. Because of the importance of the Pasco Gravels to this study, they have been subdivided into sand (Upper Pasco) and gravel facies (Lower Pasco).

Subsurface geologic data generated during the Phase II investigation were consistent with the results of the Phase I investigation. Figure 3-1 through Figure 3-4 contain idealized geologic cross-sections generated from data collected during the Phase I investigation. The Phase I RI Report (Burlington Environmental, 1994) presents a more detailed description of site stratigraphy. The results of the physical soil testing performed on Phase II soil samples are provided in Appendix H.

3.2 SOIL CHEMISTRY

3.2.1 PHASE I BACKGROUND SAMPLING

Twenty-one surface soil samples (BK-01 through BK-21) and twenty-two subsurface soil samples (borings B-09, B-09R, and B-10) were collected from the Phase I Background Sampling

Area during the Phase I RI field investigation as shown in Figure 3-5. These samples were analyzed for herbicides, pesticides/PCBs, radionuclides, and priority pollutant metals. Elevated readings were detected on the organic vapor analyzer at approximately 10 feet bgs during completion of boring B-09. As a result, B-09 was terminated, and soil samples collected from 6 and 11 feet bgs were submitted for VOC and SVOC analysis in addition to the above constituents. Soil boring B-09 was then abandoned and replaced with boring B-09R. Soil samples from boring B-10 were also analyzed for VOCs and SVOCs for comparison with B-09 results. The results of the analyses of the Phase I background samples are summarized below.

- No herbicides or SVOCs were detected in any Phase I background samples.
- One pesticide (4,4-DDE) was detected in surface soil from BK-05 and BK-12.
- Seven VOCs (ethylbenzene, toluene, total xylenes, acetone, 2-butanone, chloroform, and methylene chloride) were detected in subsurface samples from B-09 and B-10. Ethylbenzene, toluene, total xylenes, acetone, and 2-butanone concentrations were all below practical quantitation limits and were qualified as estimated results by the analytical laboratory. Chloroform and methylene chloride were also detected in the method blank and therefore the results of these analyses are not considered representative of site conditions.
- Various radionuclides and priority pollutant metals were detected at low levels in surface and subsurface background samples.

A complete discussion of the analytical results and statistical methods used in establishing site background levels for radionuclides and priority pollutant metals in surface and subsurface background samples is provided in the Phase I RI Report (Burlington Environmental, 1994).

3.2.2 PHASE I BORINGS

Soil samples were collected from just above the water table in boreholes MW-10S, MW-11S, MW-20S, and MW-22S during the Phase I field investigation (Figure 2-3). These samples were analyzed for VOCs, SVOCs, pesticide/PCBs, and priority pollutant metals. The results of the Phase I analyses are summarized as follows.

1. Three pesticides, DDT (30.3 µg/kg), endrin (41.8 µg/kg), endrin aldehyde (5.04 µg/kg), and endrin ketone (3.79 µg/kg), were detected in the sample from 69 feet bgs

in soil collected from MW-10S. No pesticides were detected in samples from MW-11S, MW-20S, MW-22S.

2. Di-n-butyl-phthalate, bis-(2-ethylhexyl)-phthalate, and di-n-octyl-phthalate were detected in samples submitted for SVOC analyses. Di-n-butyl-phthalate, and bis-(2-ethylhexyl)-phthalate were also detected in the method blanks and as a result these analyses are not considered representative of site conditions. Di-n-octyl-phthalate was detected below the practical quantitation limits in the sample from 69 feet bgs in MW-10S and was qualified as an estimated concentration by the analytical laboratory.
3. Ethylbenzene, toluene, total xylenes, acetone, 2-butanone, chloroform, and methylene chloride were detected in samples submitted for VOC analyses. Ethylbenzene, toluene, total xylenes, 2-butanone, and methylene chloride concentrations were all below practical quantitation limits and were qualified as estimated results by the analytical laboratory. Chloroform and acetone were also detected in the method blank, and therefore the results are not considered representative of site conditions.
4. All priority pollutant metals were at or below site background concentrations.

A more detailed discussion of soil samples collected from MW-10S, MW-11S, MW-20S, and MW-22S during the Phase I field investigation is provided in the Phase I RI Report (Burlington Environmental, 1994).

3.2.3 PHASE II BORINGS

No VOCs or herbicides were detected in the soil samples collected from MW-23S, MW-24S, MW-27S, or MW-28S during the Phase II field work (Figure 2-3). All priority pollutant metals detected in soil samples collected from these borings were at or below site background concentrations as defined in the Preliminary Risk Assessment performed as part of the Phase I RI. Summary tables containing the results of these analyses are provided in Appendix I.

3.3 SITE HYDROGEOLOGY

The hydrogeology of the Pasco Landfill site has been characterized during the Phase I RI and previous investigations. A brief description of previous results is provided below. Additional information can be found in the Phase I RI Report (Burlington Environmental, 1994). The Phase II RI has resulted in substantial new information on groundwater elevations and groundwater flow. This information is presented below.

3.3.1 PREVIOUS WORK

Previous work done to characterize the hydrogeology of the Pasco Landfill site includes information gathered from work performed prior to the Phase I RI and the results of the Phase I RI. Work performed prior to the Phase I RI is chronicled in the Phase I RI Report (Burlington Environmental, 1994) along with a detailed description of the work completed as part of the Phase I RI. Following is a summary of the work completed for the Phase I RI hydrogeology characterization effort.

The Phase I hydrogeologic characterization effort consisted primarily of the following work categories:

- installation of 18 groundwater monitoring wells;
- geologic logging and physical testing of subsurface soil samples;
- continuous and quarterly measurement of groundwater elevations; and
- field hydraulic testing of the unconfined aquifer (pumping test).

A total of 18 groundwater monitoring wells were installed at the site during Phase I; all were screened in the unconfined aquifer. In addition, well OW-15 was installed for use as an observation well in the aquifer pumping test performed during the Phase I RI field investigation. Subsurface soil samples were collected for geologic logging, chemical analysis, and physical and engineering characterization from 13 exploratory boreholes, 2 landfill gas probe boreholes, and 18 monitoring well boreholes. Soil samples from three boreholes (MW-12I, MW-13S and MW-14S) were analyzed for one or more physical properties including moisture content, dry unit weight, plasticity index, vertical hydraulic conductivity, specific gravity, total porosity, particulate organic carbon content, and cation exchange capacity.

Groundwater elevations were measured in wells, both on a quarterly basis and continuous basis. For the quarterly monitoring, water levels in monitoring wells across the site were measured once every one to three months over a six-month period. Groundwater elevation contour maps were generated from these data. In addition, the barometric pressure and the water levels were measured continuously in a three-well cluster (MW-17SR, MW-17I, and MW-17DR) over a 41-day period.

A series of aquifer pumping tests were conducted at the site during the Phase I investigation to estimate the horizontal hydraulic conductivity of the unconfined aquifer. The tests included a step-rate pumping test, a constant-rate pumping test, and a hydraulic head recovery test. The step-rate test was conducted to determine the proper discharge rate for the constant-rate test. During the constant-rate test, the discharge rate was approximately 106 gallons per minute and the test duration was 72 hours. The duration of the hydraulic head recovery test was approximately 48 hours.

3.3.2 HYDROSTRATIGRAPHY

An analysis of geologic and hydrogeologic data collected from the Pasco Landfill site and other areas of the Pasco Basin indicates that four broad hydrostratigraphic units are present in the subsurface. These units are:

1. the unsaturated zone (including eolian sands, Touchet beds, and unsaturated portions of the Upper Pasco Gravels);
2. the unconfined aquifer system (including saturated portions of the Lower Pasco Gravels and the Middle Ringold Formation);
3. the confining layer (made up of the Lower Ringold Formation and low permeability flows of the Columbia River Basalt); and
4. the confined aquifer system (made up principally of the more permeable interflow and interbed zones of the Columbia River Basalt Group).

The unsaturated zone, the unconfined aquifer, and the confining layer (items one through three above) were each encountered during site investigation drilling. None of the site wells or borings penetrated below the base of the Lower Ringold (the confining layer).

Waste management zones at the Pasco Landfill were built upon and into the unsaturated (vadose) zone. The unconfined aquifer system is the major source of domestic and agricultural water in the region. Groundwater monitoring has identified impacts to the unconfined aquifer system from the waste zones. For these reasons, the Phase I and II RI investigations have focused on understanding the unsaturated zone and the unconfined aquifer system.

The unsaturated zone beneath the site ranges in thickness from approximately 20 feet at the northwest corner of the Municipal Landfill to greater than 80 feet at the eastern portions of the site. The unsaturated zone is made up of the Touchet beds, and most of the Upper Pasco Gravels. These

units consist primarily of interbedded sands, silts, and gravels, with a general coarsening downward sequence.

The unconfined aquifer system beneath the site includes saturated portions of the Upper Pasco and Lower Pasco Gravels and the Middle Ringold Formation (the Upper Ringold was not encountered beneath the site). The thickness of the unconfined system ranges from about 55 feet to 75 feet and averages about 65 feet thick. The unconfined aquifer is dominated by the sands and gravels of the Middle Ringold Formation while the silty clays of the Lower Ringold make up the underlying confining layer.

Based on regional studies, permeable interflows and interbed zones of Columbia River Basalt make up the confined aquifer system. No wells or borings have been installed in the confined aquifer beneath the Pasco Landfill site.

One offsite upgradient well, five onsite wells, and fourteen offsite shallow groundwater monitoring wells were installed in the unconfined aquifer during the Phase II investigation. Each of these wells was completed in the Upper Pasco Gravels with the exception of MW-12ID which was completed in the upper part of the Middle Ringold Formation. Please refer to the Phase I RI Report (Burlington Environmental, 1994) for an expanded description of the site hydrostratigraphy.

3.3.3 GROUNDWATER ELEVATION DATA

Groundwater elevation measurements were collected quarterly from each well using an electronic water-level indicator prior to collection of groundwater samples. In addition to quarterly measurements, groundwater elevation measurements were collected continuously from three shallow groundwater monitoring wells (MW-10S, MW-28S, and MW-23S) at four-hour intervals during two separate periods using downhole pressure transducers. The first period of continuous monitoring began in June 1995 and continued until July 1996. The second period began in December 1996 and was continued until June 1997. Shallow groundwater monitoring well MW-10S was equipped with a down hole pressure transducer and a barometric pressure transducer linked to a multi-channel data logger. Wells MW-23S, and MW-28S were equipped with down hole pressure transducers linked to single-channel data loggers. The data from the

data loggers were downloaded quarterly to a laptop computer and returned to Philip's Seattle office for evaluation.

3.3.3.1 QUARTERLY MONITORING

Data from monitoring wells installed in the shallow portions of the unconfined aquifer were used to construct groundwater elevation contour maps to characterize flow conditions beneath the study area. It is important to note that not all of the wells were available for measurement during every event. For example, in June 1995 only 38 shallow monitoring wells existed at the site. As additional wells were installed, data from these points became available. In July 1996, data from 49 wells were used. For this reason, maps generated from the more recently completed monitoring events contain more data points and therefore may be more representative of site conditions. Quarterly groundwater elevation measurements were collected during each quarter beginning June 1995 until June 1997. The groundwater elevation data are presented in Appendix J.

Groundwater elevation contour maps for the shallow portion of the unconfined aquifer were generated for June, September, and December 1995; February, March, April, July, September, and December 1996; and February and June 1997 and are provided in Figures 3-6 through 3-16. All of the maps exhibit the following general pattern; groundwater elevations are highest in the northeast portion of the site and decrease toward the southwest portion of the site, indicating a dominant groundwater flow direction to the southwest. The groundwater flow gradient shifts locally towards the south in the area adjacent to Zone E and the Municipal Landfill before returning to the southwest. This shift in hydraulic gradient is clearly visible in the 350-, 351-, and 352-foot contour lines on the groundwater elevation contour maps for February, March, April, July, and December 1996.

Data from Offsite Wells installed to the south of State Route 12 indicate that the groundwater flow direction shifts to almost due south downgradient from the site. Data from the Offsite Wells also indicate the presence of a localized zone of increased groundwater elevations in the area surrounding wells MW-34S and MW-37S. This apparent groundwater mound has been observed in groundwater elevation data during all monitoring events. Additional

discussion, including an evaluation of the hydrogeologic properties of the unconfined aquifer downgradient from the site, is provided in Section 3.2.3 below.

Evaluation of the groundwater elevation data indicates that the apparent horizontal hydraulic gradient is greatest in the northern and central portions of the site with consistently lower values observed in the portion of the unconfined aquifer located to the south of the site (Figures 3-6 through 3-16 and Tables 3.1 and 3.2). Calculated hydraulic gradients range between approximately 0.0028 and 0.0045 in the northern portion of the site, and approximately 0.007 and 0.0025 across the central portion of the site (Table 3.1). The hydraulic gradient in the shallow portion of the unconfined aquifer beneath the site was estimated by calculating the hydraulic gradient between wells NW-5 and MW-16S for the northern portion of the site and between wells MW-16S and MW-22S and wells MW-20S and MW-14S for the central portion of the site.

Horizontal hydraulic gradients were also calculated for the portion of the unconfined aquifer penetrated by the Offsite Wells (Table 3.2). Horizontal hydraulic gradient were calculated for four separate sets of wells (MW-22S to MW-30S, #1 to MW-29S, MW-29S to MW-38S, and MW-38S to MW-42S) to provide an evaluation variations in hydrogeologic properties downgradient from the site. The hydraulic gradient between wells MW-22S and MW-30S was used to evaluate the hydrogeologic conditions in the unconfined aquifer to the southwest of the site. Three sets of wells (well #1 and MW-29S, MW-29S, and MW-38S, and MW-38S and MW-42S) were used to assess the hydraulic potential in the unconfined aquifer along a pathway extending from the southern boundary of the site (well #1) towards well MW-42S, the farthest downgradient well from the site. This pathway corresponds roughly with the distribution of VOCs in the Offsite Wells (Section 3.13, below).

As shown in Table 3.2, the horizontal hydraulic gradient between wells MW-22S to MW-30S (southwest of the site) consistently ranged between approximately 0.0009 and 0.0011. The apparent hydraulic gradient varied significantly along the pathway from well #1 to MW-42S. Between wells #1 and MW-29S, the hydraulic gradient ranged between 0.0014 and 0.0021. Farther south, between wells MW-29S and MW-38S, the hydraulic gradients were substantially lower ranging from 0.0002 to 0.0004. Between wells MW-38S and MW-42S, the hydraulic gradients increased somewhat ranging between 0.0008 and 0.0009.

An evaluation of the vertical hydraulic gradient in the unconfined aquifer beneath the site was performed by comparing groundwater elevation data from the three wells that make up well cluster MW-17 (MW-17SR, MW-17I, and MW-17DR). Each of these wells was constructed with 10-foot screened sections. The elevations of the tops of the well screens are 350.36, 337.99, and 291.25 feet NGVD 1929, respectively. Groundwater elevation data for well cluster MW-17 are provided in Table 3.3. Figure 3-17 shows the time variation of the cluster MW-17 quarterly water-level data, from both Phase I and Phase II.

Using quarterly groundwater elevation data, estimates were made of the vertical gradients between the upper pair of wells in the cluster (MW-17S and MW-17I), and between the lower pair (MW-17I and MW-17DR). Flow conditions in the MW-17 cluster were found to vary between mixed convergent and mixed divergent. The term mixed convergent is used to identify the existence of a downward gradient between the shallow and intermediate wells in combination with an upward gradient between the intermediate and deep wells. Similarly, the term mixed divergent is used to describe conditions where an upward gradient exists between the shallow and intermediate wells in combination with a simultaneous downward gradient between the intermediate and deep wells.

Groundwater elevation data indicate that the vertical gradient in the vicinity of well cluster MW-17 varied from downward between both well pairs, mixed convergent, or mixed divergent during the quarterly monitoring events of the Phase I RI. There was no apparent trend in the estimated vertical gradient with time, for either of the well pairs in the cluster, except that the gradient between the upper pair of wells was downward for three consecutive monitoring events (January, February and March of 1993). The gradient between the lower pair of wells was upward as often as it was downward. The vertical gradient at MW-17, estimated from the Phase I data, ranges from 0.0004 between the two lower wells, to 0.054 between the two upper wells. For every monitoring event, the gradient estimate for the lower pair of wells was of lesser magnitude than for the upper pair.

The Phase II quarterly monitoring data for well cluster MW-17 also did not reveal any prominent patterns; the estimated gradient varied from upward between both well pairs, downward between both well pairs, mixed convergent, or mixed divergent. Between the upper pair of wells, the estimated gradients were upward in 4 events and downward in 3 events.

Between the lower pair of wells, the gradient was upward for 3 events and downward for the remaining 4 events. Vertical gradient estimates from the Phase II data vary in magnitude from 0.00021 between the two lower wells, to 0.064 between the two upper wells.

A comparison of vertical gradient estimates from the Phase I and Phase II measurements revealed the following similarities between the Phase I and Phase II data. For both Phase I and II monitoring events conducted in March, the hydraulic gradient between the upper wells was downward, and the gradient between the lower wells was upward. In contrast, June data for both Phase I and II show upward gradients between the upper wells and the downward gradients between the lower wells.

3.3.3.2 CONTINUOUS MONITORING

As stated above, groundwater elevation data were collected continuously from wells MW-10S, MW-23S, and MW-28S during two separate events. The first event was from June 1995 to July 1996. The second event began in December 1996 and was still in progress upon submittal of this report. Data collected up until June 1997 were evaluated for the Phase II RI Supplement.

Evaluation of the continuous monitoring data indicates a series of short-term fluctuations in groundwater elevations in the three wells superimposed on a long-term, cyclic variation (Figure 3-18 and 3-19). Temporal fluctuations of the groundwater elevations for both the long-term and the short-term data appear to be well correlated between the three wells. The short-term fluctuations of groundwater elevations in wells MW-10S and MW-28S appear to be more strongly correlated than those of well MW-23S with either of the other two wells. However, the short-term fluctuations at well MW-23S appear to be attenuated relative to those of the other wells, and this may mask an otherwise stronger correlation.

The long-term variation in the data collected during the first monitoring event (from June 1995 to July 1996) appears to consist of an annual fluctuation in water levels, with water levels at their highest during April, and lowest near the end of September. This trend appears to be repeated in the data collected during the second monitoring event, with water levels rising steadily from December 1996 through April 1997 and exhibiting a steady decline by June 1997.

The cause of the long-term fluctuation is unknown, but may potentially be related to seasonal changes in local water usage, such as irrigation of the adjacent agricultural fields.

The amplitude of the long-term water-level fluctuations appear to be greatest in well MW-28S, and least in well MW-10S during both sampling events. However, due to a programming error in the data collection software, no data was collected from well MW-10S during the 2nd Quarter 1996. Therefore, the estimated amplitude of long-term fluctuations is of somewhat less certainty in well MW-10S than in the other wells.

The short-term fluctuations of groundwater elevations in the three wells appear to occur with periods of a few days or less. For example, there appears to be a prominent diurnal cycle in the water-level variations, suggesting that the water levels may be responding to diurnal barometric pressure cycles. This relationship between the temporal variations in barometric pressure and groundwater elevation at well MW-10S are clearly seen in Figures 3-20 and 3-21. Both exhibit a prominent diurnal component and as expected, there appears to be a strong negative correlation between the temporal fluctuations of these two variables, with no appreciable time lag.

Figures 3-22 through 3-24 contain plots of continuous monitoring data collected during the period from December to June from both monitoring events. As can be seen, the groundwater elevations were approximately 0.3 feet higher in each of the three wells during December 1996 than in December 1995. Although the initial water levels were higher in December 1996, the water levels in each of the three wells behaved consistently throughout March during both 1995 and 1996. Water levels showed a gentle decrease in the period from April 1996 to June 1996. However, during May 1997, rapid changes in groundwater elevation were observed in well MW-23S in the form of sudden decreases in water levels (on the order of one-half to one foot), followed by a recovery periods of several days during which water-level increases were observed. This pattern was repeated through June 1997.

Similarly, the continuous monitoring data from well MW-28S showed a gentle decrease in the period from April 1996 to June 1996, but remained at approximately their maximum levels throughout May 1997 before beginning to decline in June 1997. The cause of these fluctuations in water levels is unclear. However, the site is located adjacent to an agricultural area which utilizes water from the unconfined aquifer for irrigation purposes, and the

fluctuations in the data from MW-28S may be related to variations in pumping rates from the irrigation well. This effect was not observed in the 1996 data; however, the agricultural use of the property had changed. During 1996, this area was used for the production of wheat, which does not require heavy irrigation. Potatoes were grown in this area during 1997. These plants require significantly larger amounts of water, especially during late spring.

3.3.4 HYDROGEOLOGIC PROPERTIES

The hydrogeologic properties of the hydrostratigraphic units underlying the Pasco Landfill site were inferred primarily from the results of laboratory and field hydraulic tests conducted as part of the Phase I RI, and to a lesser degree from the results of previous investigations. Details on the hydrogeologic properties can be found in the Phase I RI Report (Burlington Environmental, 1994).

Groundwater flow in the unconfined aquifer beneath the site has been characterized in two ways, specific discharge and seepage velocity. Specific discharge represents the volumetric discharge of groundwater through the aquifer per unit surface area perpendicular to the direction of flow. The horizontal specific discharge can be calculated by multiplying the horizontal hydraulic conductivity by the hydraulic gradient as shown in the following simplified form of Darcy's Law:

$$q = -Ki$$

where

- q horizontal specific discharge (cm/s),
- K horizontal hydraulic conductivity (cm/s), and
- i horizontal hydraulic gradient (dimensionless).

The horizontal hydraulic conductivity for the unconfined aquifer was estimated at 0.43 cm/s (approximately 1219 ft/day) from pumping test data collected as part of the Phase I RI. Horizontal hydraulic gradient values estimated from groundwater elevation maps generated from

onsite wells, as well as calculated specific discharge rates for the unconfined aquifer beneath the site, are provided in Table 3.1.

In the second approach, the average horizontal seepage velocity (average linear velocity) of the flowing groundwater is estimated using the following relationship:

$$V_{\text{seepage}} = \frac{q}{n_e}$$

where

$$\begin{aligned} V_{\text{seepage}} &= \text{seepage velocity (cm/s),} \\ q &= \text{horizontal specific discharge (cm/s), and} \\ n_e &= \text{effective porosity (dimensionless)} \end{aligned}$$

Calculated horizontal seepage velocities for the unconfined aquifer beneath the site are presented in Table 3.1. An effective porosity of 0.30 was assumed for the shallow aquifer. The actual horizontal seepage velocity may be higher than these values at places where the hydraulic conductivity is greater than 0.43 cm/s (approximately 1219 ft/day) or where the effective porosity is lower than the assumed value of 0.30.

As discussed in Section 3.3.1 the hydraulic gradient varies across the site (Figures 3-6 through 3-16, and Table 3.1), and as a result seepage velocities also vary. The calculated seepage velocities range between 0.0040 and 0.0065 cm/s in the northern portion of the site and between 0.0100 and 0.0065 cm/s in the central portion of the site (Table 3.1) range from approximately 0.01 to 0.0036 cm/s (28.3 to 10.2 ft/day), with average seepage velocities of 0.0055 and 0.0059 cm/s (approximately 15.5 and 16.6 ft/day), respectively. These values generally agree well with the estimated seepage velocity of 0.0053 cm/s (15 ft/day) presented in the Phase I RI Report (Burlington Environmental, 1994). However, the hydraulic gradient to the south of the site is considerably lower than that of the Phase I RI study area, resulting in a lower calculated average seepage velocity for this region (0.0014 cm/s or approximately 4 ft/day).

3.4 GROUNDWATER CHEMISTRY

3.4.1 PHASE I RESULTS

Groundwater samples were analyzed for VOCs, SVOCs, priority pollutant metals, herbicides, pesticides, dioxin/dibenzo furans, radionuclides, and minimum functional standards as part of the Phase I sampling effort. The results of this work are summarized briefly below. A complete discussion of the results of the Phase I RI groundwater sampling effort is contained in the Phase I RI Report (Burlington Environmental, 1994).

Ten organic chemicals and six inorganic chemicals were detected in groundwater at levels exceeding MTCA Method B formula values during Phase I sampling. These are: 1,1-DCE, 1,2-DCA, 1,2-DCE, TCE, PCE, vinyl chloride, benzene, toluene, 4-methyl-2-pentanone, 1,1,1-TCA, antimony, chromium, beryllium, lead, manganese, and thallium.

Of 16 compounds detected above MTCA Method B Formula values, seven indicator compounds (1,1-DCE, TCE, 1,2-DCA, 1,2-DCE (total), PCE, chromium, and manganese) were selected for additional evaluation. Indicator compounds were selected based on the number of wells in which they were detected, and their identification in the Preliminary Risk Assessment (Burlington Environmental, 1994) as having made a significant contribution to either the site hazard index or carcinogenic risk.

The highest concentrations of the Phase I indicator compounds occurred immediately downgradient (southwest) of Zone A. Of these compounds, all but TCE, 1,2-DCE, and manganese were near or below the quantitation limits at the downgradient property boundary (wells MW-10S and MW-11S) during Phase I sampling.

The Phase I RI report also contained a preliminary examination of the vertical distribution of indicator compounds detected in the three wells that make up monitoring well cluster MW-12. In general, chemical concentrations in the shallow zone were found to be approximately twice as high as in the intermediate zone, with only manganese detected above background concentrations in the deep zone.

3.4.2 PHASE II QUARTERLY MONITORING RESULTS

Groundwater from monitoring wells at the Pasco Landfill site and surrounding area has been sampled quarterly as part of the Phase II RI. Samples were analyzed for VOCs, SVOCs, herbicides, WAC 173-351-990 Appendix I and II Metals, and water quality parameters, according to the program described in Section 2.11 above. Summary tables containing complete results of analyses performed on these samples are contained in Appendix I of this document. Summary tables of the analytes detected in groundwater during both Phase I and II investigations can be found as an attachment to the Technical Report in Volume II. Phase II quarterly monitoring results are discussed by chemical group in the following subsections.

Although site cleanup levels have not been established, for the purpose of discussion, the following sections contain comparisons between calculated MTCA Method B formula values and the chemical concentrations observed in groundwater at the site.

MTCA Method B formula values represent concentrations below which no acute or chronic toxic effects on human health are anticipated for a single chemical, using the risk equations specified in WAC 173-340-720 through 750. These concentrations may not represent final cleanup levels required for the site. Final cleanup levels will be established using the results of the site risk assessment in accordance with applicable state and federal laws, and in consideration of multiple chemicals and pathways of exposure, and potential cross-media impacts.

3.4.2.1 VOLATILE ORGANIC COMPOUNDS

A general comparison between VOC concentrations measured during Phases I and II indicates that VOC concentrations in groundwater have remained fairly constant or increased slightly from Phase I to Phase II, with the greatest variabilities occurring in those wells with the highest concentrations. Several factors may have influenced this.

1. The low flow sampling technique employed during Phase II minimizes agitation and potential volatilization of the sample.
2. Laboratory detection limits for many of the VOCs were lower during Phase II resulting in detection of a greater number of compounds.
3. Groundwater sampling was performed only once during the Phase I effort, while the Phase II investigation includes five sampling events.

VOCs were detected in groundwater samples collected from both site and background wells during all Phase II sampling events. A summary table showing VOCs detected in groundwater at the site is provided as an attachment to the Technical Report in Volume II. A total of 20 VOCs were detected in groundwater at concentrations in excess of their MTCA Method B formula values (Table 3.4). Of the 20 VOCs detected above their respective MTCA Method B formula values, six (PCE, TCE, 1,1-DCE, cis-1,2-DCE, 1,2-DCA, and vinyl chloride) were selected as indicator compounds to assess the extent of impacted groundwater associated with the site. Indicator compounds were selected based on the following criteria:

- the chemical must have exceeded the corresponding MTCA Method B formula value in each of the five sampling events; and
- the chemical must have been detected in a sufficient number of wells to allow generation of a meaningful chemical contour map.

Chemical contour maps of the six indicator compounds, along with a discussion of their distributions in groundwater, are provided in Section 3.13.2 of this report.

3.4.2.2 SEMIVOLATILE ORGANIC COMPOUNDS

A total of twenty-five SVOCs were detected in groundwater samples during the Phase II investigation. Only ten were detected in samples collected during the Phase I investigation. This difference is likely due to a combination of lowered detection limits and the increased number of wells sampled during Phase II. No SVOCs were detected at concentrations exceeding the MTCA Method B formula values in any of the Phase I or Phase II sampling events. A summary table listing the SVOCs detected in groundwater during the Phase II is provided in Table 3.5. A complete listing of SVOCs detected in groundwater at the site is included in the attachment to the Technical Report (Volume II). Discussion of the distribution of SVOCs in groundwater at the various disposal zones is provided in the sections below.

3.4.2.3 HERBICIDES

Four herbicide compounds (dicamba, 2,4-D, MCPA, and 2,4,5-TP) have been detected in groundwater at the Pasco Landfill site. Three of these (Dicamba, 2,4-D, and MCPA) were detected in Zone B well EE-4 in February 1993 during Phase I sampling. In addition, MCPA

was also detected in groundwater from Zone A well EE-3 at 0.2 µg/L in June 1995, and at 0.082 µg/L in March 1996 as part of Phase II sampling. The herbicide 2,4-D was detected in well EE-2 at 0.01 µg/L during the December 1995 event, while 2,4,5-TP was detected in EE-2 at 0.024 µg/L in March 1996. The concentrations of each of the herbicides detected in groundwater at the site were well below their respective MTCA Method B formula values. A summary table of herbicides detected in groundwater at the site is provided in the attachment to the Technical Report in Volume II.

3.4.2.4 APPENDIX I METALS

Five WAC 173-351-990 Appendix I Metals (arsenic, lead, antimony, beryllium, and thallium) were detected above their MTCA Method B formula values in groundwater samples collected from the site. Arsenic was detected in 191 out of a total of 219 samples collected during the Phase I and II investigations with concentrations ranging from less than 1 to 8.9 µg/L.

Each of these detections was above the MTCA Method B formula value of 0.05 µg/L for arsenic, with the highest concentrations at the site detected in the June 1995 sample from well MW-19S (8.8 µg/L) and the April 1996 sample from offsite well MW-38S (8.9 µg/L). Arsenic was detected above the MTCA Method B formula value in 14 of the 15 samples collected from upgradient background wells NW-5, MW-20S, and MW-28S, as well as 26 of the 29 samples collected from Offsite Wells MW-29S through MW-42S. The general occurrence of arsenic across the site, as well as in upgradient wells, indicate that its presence in groundwater is not related to site activities.

Lead concentrations in groundwater have varied significantly throughout the course of groundwater monitoring at the site. Lead was detected in 10 of the 28 wells sampled during the Phase I investigation, including detected concentrations of 22.3 µg/L and 17.1 µg/L in wells MW-15S and MW-17SR, respectively. These were the highest lead concentrations detected during Phase I sampling, and were the only two wells that exceeded MTCA Method A value (5 µg/L) during Phase I sampling (there is no MTCA Method B formula value listed for lead).

Lead was only detected in 1 of the 32 wells sampled during June 1995 (2 µg/L in well #8), but was detected in all 42 wells sampled during September and October 1995, including all upgradient, background, and offsite wells. Lead concentrations exceeded the MTCA Method A

value in 19 of the 42 wells sampled during September and October 1995, including 8.6 µg/L in upgradient well NW-5, but were below detection limits in each of the same 42 wells during December 1995. Lead was detected in 6 of the 45 wells sampled during March 1996 (all below the Method A value) and in 4 of the 21 wells sampled during July 1996 with one above the MTCA Method A value (13 µg/L in EE-3).

No clear trend in the data has been identified; however it is interesting to note that groundwater elevations across the site were at their lowest during September 1995, when lead was detected in all 42 wells. This observation, coupled with the high degree of variability in the number of detections and concentrations of lead in groundwater at the site, as well as in upgradient and background wells over the course of Phase II sampling, indicates that its presence is not related to site activities.

Antimony has been detected in a total of 37 samples from 28 wells at the site. Only 9 of the 28 wells contained antimony during more than one sampling event. Only four samples contained antimony concentrations above the MTCA Method B formula value: the February 1993 samples from wells #1 and EE-3; the September 1995 sample from well #9; and the July 1996 sample from well EE-3. Well EE-3 was the only well that exceeded the MTCA Method B formula value for antimony on more than one occasion (February 1993 and July 1993).

A comprehensive evaluation of the analytical results for antimony is somewhat problematic due to the high degree of variability in sampling data. For example, antimony was only detected in one sample during the 2nd Quarter 1995 (2.1 µg/L in well MW-30S). It was detected in 13 samples during the 3rd Quarter 1995 sampling event, but was also reported at similar concentrations in the associated laboratory blank, indicating potential analytical error or sample contamination by the analytical laboratory.

Similarly, antimony was not detected in any wells during the 4th Quarter 1995 or 1st Quarter 1996 sampling events, but was detected in all 21 samples analyzed during the 2nd Quarter 1996 sampling event. Antimony was not reported in the laboratory blanks associated with these samples. Additional complication results from the fact that samples collected from the 1st Quarter 1995 through 1st Quarter 1996 were analyzed by a different laboratory than those collected during the 2nd Quarter 1996. It is unclear what effect this may have had on the reported antimony values.

The degree of variability in the number of detections and concentrations of antimony in groundwater at the site, as well as its occurrence in upgradient and background wells over the course of Phase II sampling, indicates that its presence is not the result of waste handling practices at the site.

Beryllium was detected once in each of the following five wells: EE-3, #4, #5, MW-15S, and MW-35S. Each of these detections was above MTCA Method B formula value for beryllium (0.0203 µg/L). Three of these detections (#4, #5, and MW-15S) occurred during the Phase I field investigation. Beryllium was only detected twice during the Phase II investigation: the duplicate sample collected from Offsite Well MW-35S during October 1995 (beryllium was not detected in the primary sample), and the July 1996 sample from well EE-3. Beryllium has not been detected in any well on more than one occasion.

Thallium was detected a total of six times during Phase II sampling. Thallium concentrations were above the MTCA Method B formula value (1.12 µg/L for thallium salts) in a total of five samples from four wells: well EE-5 in February 1993; wells #1, #9, and EE-5 in September 1995; and EE-3 in the July 1996 sampling event. The only other sample containing detectable thallium concentrations was the September 1995 sample from well EE-7. Well EE-5 was the only well that contained detectable thallium concentrations on more than one occasion.

No clear trend in thallium concentrations was observed; however, it is interesting to note that the majority of detections occurred during the September 1995 sampling event, which corresponds to the lowest water levels observed at the site. The July 1996 sample from well EE-3 contained the highest thallium concentrations observed at the site. The July 1996 sample from EE-3 also contained the highest lead, antimony, beryllium, and antimony concentrations observed at the site, as well as the lowest pH and dissolved oxygen values observed in well EE-3.

In any event, the degree of variability in the number of detections and concentrations of beryllium and thallium in groundwater at the site indicates that its presence is not the result of site activities, although there may be some relationship between their occurrence and localized changes in groundwater geochemical or natural background conditions. A summary of WAC 173-351-990 Appendix I and II Metals exceeding MTCA Method B formula values at the site is provided in Table 3.6.

3.4.2.5 APPENDIX II METALS

WAC 173-351-990 Appendix II metals include calcium, magnesium, iron, manganese, potassium, and sodium. Calcium and magnesium were detected in all wells sampled during all five sampling events. Calcium concentrations ranged from 41,500 to 136,000 µg/L. Calcium levels were in excess of 80,000 µg/L in wells EE-3, MW-16S, and MW-17SR for all five sampling events and at least one sampling event for wells #2, #4, #5, #9, MW-23S, and MW-39S.

Magnesium concentrations ranged from approximately 15,800 to 40,400 µg/L with concentrations exceeding 30,000 µg/L in wells #2, MW-16S, and MW-23S. The highest magnesium concentrations occurred in well MW-23S, which contained 40,400 µg/L in December 1995 and 36,800 µg/L in March 1996.

Iron was present at levels ranging from less than the detection limit to 14,300 µg/L. There were four wells in which iron was detected during all five events; EE-3, EE-8, MW-19S, and MW-21DR. The highest iron concentrations were in well EE-3, at 10,800 to 14,300 µg/L.

EE-3 was the only well at the site that contained manganese concentrations above the MTCA Method B formula value of 2,240 µg/L. Manganese concentrations in EE-3 ranged from a low of 1,970 µg/L to a high of 2,560 µg/L and exceeded the above MTCA Method B formula value in EE-3 during all sampling events except September 1995.

Dissolved oxygen (DO) concentrations in well EE-3 were the lowest observed at the site and were consistently 1.2 µg/L or lower. In general, the solubility of manganese increases under reducing conditions such as those observed at well EE-3. This suggests that the increased concentrations of manganese observed in well EE-3 may be the result of changes in groundwater chemistry due to anaerobic (reducing) conditions beneath Zone A. This conclusion is supported by the fact that the lowest manganese concentrations observed in well EE-3 (1,970 µg/L in September 1995) correspond with the highest DO readings (1.2 µg/L), while the highest manganese concentrations in well EE-3 (2,560 µg/L in July 1996) correspond with the lowest DO readings (0.1 µg/L). This is further supported by the fact that the only other samples that exceeded 500 µg/L manganese were the June 1995 and March 1996 samples from well #4 which

contained 510 and 1,360 µg/L of manganese, respectively. DO readings from these wells were 0.4 and 0.7 mg/L for samples collected during June 1995 and March 1996, respectively.

Both potassium and sodium were detected in groundwater from all of the sampled wells during all five events. Potassium levels ranged from 4,640 to 11,000 µg/L. Sodium levels ranged from 25,100 to 45,900 µg/L.

3.4.2.6 WATER QUALITY PARAMETERS

The term water quality parameters in this report is used in reference to the following list of parameters: bicarbonate or carbonate alkalinity (as CaCO₃), chloride, sulfate, total alkalinity (as CaCO₃), ammonia (as N), total organic carbon (TOC), total dissolved solids (TDS), chemical oxygen demand (COD), nitrate (as N), and nitrite (as N).

Bicarbonate (carbonate alkalinity) is defined as the milli-equivalents (meq) of acid per liter of sample required to reach the phenolphthalein endpoint (pH = 8.3). Total alkalinity is defined as the milli-equivalents of acid per liter of sample required to reach the methyl orange endpoint (pH = 4.3). Each measurement is expressed in units of equivalent mg/L of calcium carbonate (CaCO₃). The results for carbonate alkalinity and total alkalinity yielded equivalent values for all wells and all sampling events, indicating that bicarbonate is the only major species contributing to alkalinity at the site.

Bicarbonate/alkalinity in site groundwater ranged from 153 to 441 mg/L (as CaCO₃). The highest levels of bicarbonate/alkalinity were detected in well MW-16S for three of the four sampling events with levels varying from 332 to 433 mg/L (as CaCO₃). The single highest concentrations of bicarbonate/alkalinity were 441 mg/L (as CaCO₃) in well MW-23S during the December 1995 event.

Chloride in groundwater varied from 22.4 to 57.1 mg/L with the highest concentrations occurring in EE-3 and MW-19S. Sulfate concentrations in groundwater ranged from 44.9 to 82.1 mg/L with the lowest sulfate levels found in well EE-3 during each of the four sampling events.

Phase II TOC results were above detection limits in between one and eleven wells per event and ranged in concentrations from less than 1 mg/L to 40 mg/L. During all sampling events except September 1995, the highest TOC levels occurred in well EE-3, where

concentrations ranged from 11 to 40 mg/L. TOC was only above detection limits in one well (1.3 mg/L at well #1) during the September 1995. The TOC results for upgradient well NW-5 were non-detect during all five events.

TDS in groundwater ranged from 330 to 640 mg/L during Phase II sampling. TDS levels were 500 mg/L or higher in wells #4 and MW-16S for all five sampling events, and in three of the five events in wells EE-3, MW-17SR and MW-23S. TDS levels for upgradient well NW-5 were from 370 to 440 mg/L.

COD levels in groundwater ranged from less than the detection limit (10 mg/L) to 120 mg/L. The COD levels reported for well EE-3 were the highest, or among the highest, during each event. COD levels at well EE-3 ranged from 29 to 120 mg/L. COD levels for the upgradient well NW-5 were from 11 to 15 mg/L.

The results of ammonia (as N) analyses of groundwater were highly variable with between 3 and 36 detections per sampling event and concentrations ranging from below detection limit (5 µg/L as N) to 170 µg/L (as N). The highest number of detections (36) occurred during December 1995, while ammonia was only detected in three wells during June 1995 and July 1996. Although not always the highest ammonia levels, the concentrations in well EE-3 remained high (40 to 50 µg/L as N) relative to most of the other wells during the last three sampling events. Ammonia was not detected in the upgradient well NW-5 during any of the five sampling events.

As shown in Table 3.7, mean oxidation-reduction potential (ORP) values ranged from -84 millivolts (mV) at well EE-3 in July 1996 to +333 mV in well MW-17SR in March 1996 with oxidative conditions generally prevailing across the site. Exceptions to this are observed in wells EE-3 and #4 in March 1996. EE-3 consistently shows a reducing environment with average ORP values of approximately -80 mV. Well # 4 was slightly reducing (-1 mV) during the March 1996 sampling event.

Mean DO concentrations range from a high of 6.9 mg/L in Offsite Well MW-32 to a low of 0.3 in well EE-3 (Table 3.7). The lowest DO concentrations consistently occur in wells EE-3, #4, MW-16S, and MW-23S, in the areas adjacent or hydraulically downgradient from Zone A or the Municipal Landfill. The presence of methane and carbon dioxide above ambient atmospheric concentrations, accompanied by reduced oxygen concentrations in landfill gas and

soil-gas probes, indicate anaerobic biodegradation in these areas. However, it is unclear whether the reducing conditions are the result of biological consumption of aerobically degradable chemical compounds (e.g., acetone, toluene, xylenes, etc.), decay of organic materials in the municipal waste in the Municipal Landfill or Balefill Area, or a combination of the two.

Nitrite (as N) was only detected once: the December 1995 sample from well MW-12ID. Nitrate (as N) was detected in all wells during all sampling events, with the exception of the March and July 1996 samples from well EE-3. Well EE-3 had the lowest nitrate levels during all five events; typically an order of magnitude or more lower than in the other wells across the site. Well EE-3 also exhibited consistently low dissolved oxygen concentrations. Anaerobic bacteria are known to utilize the nitrate ion as a substitute for molecular oxygen during metabolism, indicating that anaerobic biometabolism is occurring in the vicinity of well EE-3.

In addition, the chlorinated solvents PCE and TCE are known to undergo sequential dehalogenation by microbes under anaerobic and methanogenic conditions, according to the transformation sequence shown in Figure 3-25. As stated previously in Section 3.4.2.1, PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride have each been observed in groundwater emanating from Zone A and the Municipal Landfill. Together, the decreased nitrogen and dissolved oxygen concentrations, along with the presence of the PCE, TCE and their biotransformation products, indicate that anaerobic degradation of these chlorinated compounds is occurring beneath Zone A and the Municipal Landfill.

3.4.2.7 CATION/ANION BALANCE

A fundamental condition of natural groundwater systems (and all electrolyte solutions) is that a state of electroneutrality exists. That is, on a macroscopic scale the sum of the positive ionic charges (molality of the cation species) equals the sum of the negative ionic charges (molality of the anion species) according to the *charge-balance equation*:

$$\sum zm_c = \sum zm_a$$

where z is the ionic valence, m_c the molality of the cation species, and m_a the molality of the anion species. Significant deviation from electroneutrality is an indication of analytical errors or

failure to include ionic species that were present at significant concentrations in groundwater. Thus, an indication of accuracy of water quality analyses can be obtained through the *charge-balance error equation*:

$$E = \frac{\sum zm_c - \sum zm_a}{\sum zm_c + \sum zm_a} \times 100$$

where E is the *charge-balance error* expressed in percent. An error of approximately 5% is generally considered to be within acceptable limits.

The *charge-balance error* was computed for site groundwater by comparing the molality of calcium, iron, magnesium, manganese, potassium, and sodium (the major cation species) with the molality of bicarbonate, chloride, nitrate, and sulfate (the major anion species). As can be seen in Table 3.8, the *charge-balance error* for the majority of samples was less than 5 % difference and judged to be within acceptable limits. A notable exception is the December 1995, sampling event at well #4, which had a *charge-balance error* of approximately 18 %. This error was presumably caused by unusually low calcium concentrations in the December 1995 data resulting in an overall negative charge. However, as can be seen in Table 3.8 even with the relatively high error during this quarter, the average charge-balance error for well #4 was still only 5.0. Wells #3 and EE-3 each had a single exceedance of the 5.0% error criteria. These two minor exceedances (approximately 9.0%) occurred during different quarters and are not considered significant.

The *charge-balance error* was computed for groundwater samples collected from the Offsite Wells by comparing the molality of calcium, iron, magnesium, manganese, potassium, and sodium (the major cation species) with the molality of bicarbonate, chloride, nitrate, and sulfate (the major anion species). As can be seen in Table 3.9, the *charge-balance error* for the majority of samples was less than 5 % difference with the *charge-balance error* falling below 5 % for all wells except MW-32S which had an average *charge-balance error* of 5.1 %.

The highest *charge-balance error* occurred in well MW-33S with had a charge-balance error of approximately 6 % in March 1996. However, this relatively minor exceedance of the 5.0% error criteria is not considered significant, and the accuracy of water quality analyses was generally considered to be within acceptable limits.

Another method of assessing water quality parameters is through an examination of the distribution of the major cations and anions in groundwater. As can be seen in Table 3.10, no appreciable difference was observed in these parameters between the various waste zones, with the exception that the groundwater from the Landfill Wells tend to exhibit slightly higher calcium to bicarbonate ratios than groundwater associated with the remainder of the site.

Perhaps the most useful information with respect to assessing the distribution of the Appendix II Metals comes from a comparison between the ratios of calcium to potassium in wells associated with the various disposal zones. Although there is some variability between the wells, groundwater samples from wells located adjacent to and directly downgradient from the Municipal Landfill tend to exhibit somewhat higher calcium to potassium ratios than other wells across the site (Table 3.10).

3.5 MUNICIPAL LANDFILL

3.5.1 LANDFILL GAS

Landfill gas samples were collected from each of the landfill gas probes during three quarterly sampling events. Each sample was analyzed in the field for oxygen, hydrogen, hydrogen sulfide, carbon dioxide, methane, and LEL. The results of these analyses revealed elevated concentrations of methane and carbon dioxide concentrations accompanied by reduced levels of oxygen in all landfill gas probes, indicating that waste contained in the former Municipal Landfill is undergoing biodegradation. The highest methane concentrations occur in landfill gas probe clusters LFG-01 and LFG-02 along the western boundary of the Municipal Landfill and at LFG-04 along the southeast corner of the Municipal Landfill. These results indicate that waste contained in the former Municipal Landfill is undergoing anaerobic biodegradation.

Hydrogen gas was only detected in two samples: the samples collected from LFG-02S and LFG-02I during September 1995. Hydrogen sulfide was not detected in any landfill gas probes. A summary of landfill gas field parameters is provided in Table 3.11.

Landfill gas samples were also collected from each probe and submitted to an offsite laboratory for VOC analysis. A total of 34 VOCs were detected in landfill gas samples (Table 3.12). As with methane, the highest concentrations of VOCs were found in LFG-01 and LFG-02 along the

western boundary of the Municipal Landfill, with significant concentrations also detected in LFG-04 at the southeast corner of the Municipal Landfill. The lowest concentrations of methane, carbon dioxide, and VOCs were consistently detected in LFG-03, at the southern tip of the Municipal Landfill. Maps showing the concentrations of indicator compounds PCE, TCE, 1,1-DCE, cis-1,2-DCE, 1,2-DCA, and vinyl chloride in Phase II landfill gas samples are provided in Figures 3-26 through 3-31.

3.5.2 STRUCTURE MONITORING

Onsite structures, including the scale house, pump house, maintenance shop, and mobile home foundation, were monitored quarterly using a CGI to assess potential methane accumulations. No methane was detected in any onsite structure during any monitoring event.

3.5.3 GROUNDWATER CHEMISTRY, MUNICIPAL LANDFILL

Thirteen wells (#3, #4, #5, #6, #8, #9, MW-15S, MW-16S, MW-17SR, MW-18S, MW-22S, MW-23S, and MW-24S) have been designated as Landfill Wells for the purpose of providing an assessment of groundwater conditions in the vicinity of the former Municipal Landfill (Figure 2-5). Well NW-5, located hydraulically upgradient from the site, provides data concerning natural background groundwater quality.

3.5.3.1 VOLATILE ORGANIC COMPOUNDS

The results of Phase I and II groundwater monitoring indicate that VOCs from waste in the former Municipal Landfill are impacting groundwater. A total of 28 VOCs have been detected in groundwater samples collected from the Landfill Wells. The highest concentrations of VOCs were detected in wells #4, MW-16S and MW-23S along the western boundary of the Municipal Landfill. The next highest concentrations of VOCs occur in well #5, hydraulically down gradient from the southern tip of the Municipal Landfill.

A total of eight VOCs (vinyl chloride, 1,1-DCE, 1,2-DCA, TCE, PCE, 1,2-dichloropropane, 1,4-dichloropropane, and acrylonitrile) have been detected in Landfill Wells at concentrations that exceed their respective MTCA Method B formula values. Of these, all eight

exceeded MTCA Method B formula values in well #4, seven exceeded their Method B formula values in well MW-16S, and five were above Method B values in well MW-23S. A summary of analytical results for VOCs that exceeded MTCA Method B formula values in Landfill Wells is provided in Table 3.13.

Figure 3-32 provides an illustration of the distribution of VOCs that exceeded MTCA Method B formula values in Landfill Wells. As can be seen in Figure 3-32, PCE was detected in excess of its MTCA Method B formula values in all thirteen Landfill Wells, while 1,1-DCE exceeded its Method B formula value in seven wells, vinyl chloride exceeded its Method B value in six wells, and TCE exceeded its Method B value in four wells. Each of these four VOCs were detected in wells #4, #5, MW-16S, and MW-23S. Vinyl chloride and PCE were also detected above MTCA Method B formula values in Landfill Well #9. These results indicate that VOCs from the former Municipal Landfill are impacting groundwater. Groundwater monitoring also indicates that the hydraulic gradient observed in groundwater elevation data collected from this area is more southerly than other areas of the site (Figures 3-6 through 3-16).

3.5.3.2 SEMI-VOLATILE ORGANIC COMPOUNDS

Only two Landfill Wells (wells #3 and #5) were sampled for SVOCs during the Phase II RI investigation. Both wells are located hydraulically downgradient from the southern tip of the former Municipal Landfill. A total of five SVOCs (phenol, benzoic acid, dimethyl phthalate, di-n-butyl phthalate, and butyl benzyl phthalate) were detected in these wells (Table 3.14). Three of the five compounds (phenol, benzoic acid, and dimethyl phthalate) were only detected once.

Butyl benzyl phthalate was detected at concentrations below practical quantification limits in the June and September 1995 samples from well #5. Di-n-butyl phthalate was detected in wells #3 and #5 during September 1995; however, data validation results indicate that di-n-butyl phthalate was also present in the method blanks for both samples. Di-n-butyl phthalate has not been detected in any other samples collected from well #3 or #5 during the Phase II investigation.

The concentrations of all five SVOCs detected in wells #3 and #5 were well below the MTCA Method B formula values for the respective compounds. These results indicate that the Municipal Landfill is not acting as a significant source of SVOCs to groundwater.

3.6 ZONE E AND ZONE TS-1/SL-1

3.6.1 GEOPHYSICAL INVESTIGATION, ZONE E AND ZONE TS-1/SL-1

No magnetic anomalies were identified within the boundaries of Zone E during the Phase I geophysical investigation (Figure 3-33 and Figure 3-34). However, the outline of the two chlor-alkali sludge disposal cells are clearly visible on the EM-31 apparent and in-phase conductivity maps (Figure 3-35 and Figure 3-36). The location of the outline of the disposal cells identified in the EM-31 data agrees well with the boundaries reported during the closure survey.

The results of the Phase II ground magnetics survey indicate that no buried metallic waste is present in disposal zone TS-1/SL-1. However, the EM-31 apparent conductivity data indicates the presence of an east-west trending low-amplitude anomaly in the center of the zone (Figure 3-37), corresponding to the reported location of the overflow area associated with former sewage disposal pond SL-1.

The in-phase EM-31 conductivity data also exhibit a low-amplitude anomaly in the central portion of Zone TS-1/SL-1 (Figure 3-38). The fact that the trend in the in-phase anomaly runs from north to south, while the apparent conductivity anomaly trends from east to west, indicates that these anomalies are associated with different phenomena. The in-phase portion of the EM-31 signal is often indicative of buried metallic objects, however, no evidence of buried metallic objects was detected using ground magnetics. While the source of the in-phase anomaly remains unknown, it does not appear to be related to past waste handling practices.

3.6.2 BULK WASTE CHARACTERIZATION, ZONE E

The results of the Bulk Waste Characterization activities conducted during the Phase II investigation indicate that Zone E is fully covered by a vegetated soil cap approximately three feet thick and by plastic liner. As noted in Section 2.2, the plastic cover was found immediately overlying the waste. The material was blue-gray in color and clay-like. Wood chips and other debris were also noted in the material. This debris contained filter cartridges,

graphite anode supports, portions of discarded tank liners, and other material consistent with wastes associated with the chlor-alkali manufacturing processes.

Samples of the material collected from Zone E during May 1995 were submitted for waste profile analyses. These analyses included screening for corrosivity, flammability, reactivity, sulfides, cyanides, phenolics, hexavalent chromium, chlorinated compounds, and oxidizers. The material was also analyzed for total metals and TCLP heavy metals (D004 - D011). A fish bioassay was also performed to assess potential toxicity and assess the applicability of Washington Dangerous Waste regulations.

Total metals analyses of the May 1995 samples indicate the presence of barium, cadmium, chromium, lead, and mercury (Table 3.3). However, waste characterization indicates that the material is not corrosive, flammable, or reactive. The results of all other screening tests, the TCLP tests, and the fish bioassay were also negative. Data from the waste profiling analyses can be found in Appendix I.

Four VOCs (chloroform, PCE, 1,2,4-trichlorobenzene, and toluene) were detected in the waste samples collected from Zone E during May 1997 (Table 3.16). Chloroform was detected in three of the six samples (ZE-01, ZE-05 and ZE-06), and PCE was detected in two of the samples (ZE-01 and ZE-06). Toluene was detected in only one sample (ZE-06), and 1,2,4-trichlorobenzene was detected in only one sample (ZE-01). All three of the sample locations where VOCs were detected were located at the west end of Zone E (Figure 2-10). All of the VOCs detected were at concentrations well below the MTCA Method B formula values for soil. TCLP VOCs in the two composite waste samples analyzed were negative.

Of the four VOCs detected in Zone E waste samples, three (PCE, chloroform, and toluene) have also been detected in the Zone E groundwater wells. PCE was detected at 1.89 µg/kg in ZE-01 and 6.10 µg/kg in ZE-06. These levels are well below the MTCA Method B formula values for soil. PCE was detected in both Zone E Well MW-27S and Landfill Well #9 in all samples analyzed for VOCs during Phase II sampling and in well MW-19S during three of the five sampling events. PCE was detected in one groundwater sample from EE-8. The concentrations of PCE in Landfill Well #9 were higher than those in Zone E wells during every Phase II sampling event up until June 1996 when sampling of well #9 was discontinued. These data indicate the Municipal Landfill as a potential source of PCE in groundwater.

Chloroform has been detected in Landfill Well #9 and well MW-19S. The concentrations in Landfill Well #9 exceeded the concentrations measured in well MW-19S during every sampling event. These results indicate that chloroform in MW-19S is likely the result of hydraulic transport from the Municipal Landfill and not associated with Zone E. The sampling data from the Zone E waste support this conclusion, as only three of the six Zone E waste samples had detectable concentrations of chloroform (2.29 µg/kg in ZE-01, 4.60 µg/kg in ZE-05, and 13.8 µg/kg in ZE-06). None of these three samples were above MTCA Method B formula values for soil.

Toluene was also detected in groundwater from Zone E wells EE-8 and MW-27S during June 1995 sampling event, but was detected at higher concentrations in upgradient wells MW-20S, MW-28S and NW-5, as well as Landfill Well #9. Toluene was not detected in any of these wells during subsequent sampling events. Toluene was only detected in one Zone E waste sample (11.1 µg/kg ZE-06). This level is well below the MTCA Method B formula value for soil. The results indicate that the source of toluene in the groundwater is not associated with Zone E.

Total chromium was detected at low levels in all the May 1997 Zone E waste samples. The concentrations ranged from 4.69 mg/kg in ZE-06 to 7.64 mg/kg in ZE-05 (Table 3.17). Total chromium concentrations were below the MTCA Method B formula values for both trivalent chromium (80,000 mg/kg) and hexavalent chromium (400 mg/kg). No hexavalent chromium was detected in any Zone E waste samples. Elevated chromium has been detected in the groundwater from wells EE-8 and MW-19S. However, the results of the Bulk Waste Characterization Activities at Zone E indicate that the source of chromium in wells MW-19S and EE-8 is not associated with the waste in Zone E.

The results of the May 1995 Bulk Waste Characterization activities, as well as the waste profiling analyses conducted on the six additional samples analyzed in May 1997, indicate that the waste material in Zone E would not be designated as either a characteristic RCRA hazardous waste or a characteristic Washington State Dangerous Waste. The results of these analyses indicate that the waste material in Zone E does not pose a threat to human health and the environment.

3.6.3 SOIL CHEMISTRY, ZONE E AND ZONE TS-1/SL-1

3.6.3.1 PHASE I RESULTS

Subsurface soil samples in the vicinity of Zone E were collected from B-03, B-04, and B-11 during the Phase I field investigation. All samples were analyzed for SVOCs and priority pollutant metals. In addition, samples from boring B-11 were analyzed for VOCs, pesticide/PCBs, chlorinated herbicides, and radionuclides. The results of the Phase I analyses are summarized as follows:

- no VOCs, SVOCs, herbicides, or pesticides were detected;
- all radionuclides were at or below site background concentrations; and,
- all priority pollutant metals except lead and mercury were at or below site background concentrations. Both lead and mercury exceeded site background concentrations in the sample from 0.5 feet bgs in boring B-03.

A more detailed discussion of priority pollutant metals concentrations in Zone E soil samples collected during the Phase I field investigation is provided in the Phase I RI Report (Burlington Environmental, 1994).

3.6.3.2 ZONE TS-1/SL-1 SOIL BORINGS

The results of the Phase II EM-31 survey revealed the presence of a low-amplitude conductivity anomaly in the former SL-1 Lagoon Overflow area adjacent to Zone TS-1/SL-1 (Figure 2-10). The ground magnetics survey of the area did not indicate the presence of buried metallic objects that might explain the anomaly; however, elevated chromium concentrations have been detected in groundwater samples collected from EE-8 and MW-19S downgradient from Zone TS-1/SL-1. As a result, two soil borings (B-17 and B-18) were installed to assess the conductivity anomaly as a potential source of chromium in groundwater.

Hexavalent chromium was not detected in any of the soil samples collected from borings B-17 and B-18. Total chromium concentrations ranged from approximately 5 to 8 mg/kg (Table 3.17), indicating that soil in the vicinity of the conductivity anomaly adjacent to Zone TS-1/SL-1 is not likely to be acting as a significant source of the chromium detected in groundwater from monitoring wells EE-8 and MW-19S.

3.6.4 GROUNDWATER CHEMISTRY, ZONE E AND ZONE TS-1/SL-1

Three wells (EE-8, MW-19S, and MW-27S) have been designated as Zone E Monitoring Wells for the purpose of assessing potential impacts to groundwater associated with Zone E and Zone TS-1/SL-1. Wells NW-5 and MW-20S were used to provide upgradient and background data. Well NW-5 is located hydraulically upgradient from the Zone E and provides data concerning natural background conditions. Well # 9 provides a monitoring point between Zone E and the Municipal Landfill.

3.6.4.1 VOLATILE ORGANIC COMPOUNDS

Table 3.18 contains a summary of VOCs detected in wells #9, EE-8, MW-19S, MW-20S, MW-27S, MW-28S, and NW-5 during Phase II sampling. Wells EE-8, MW-19S, and MW-27S were designated as Zone E Monitoring Wells and were used for assessing of groundwater conditions in the vicinity of Zone E. Data from wells MW-20S, MW-28S, and NW-5 were evaluated to assess contaminants in groundwater upgradient from Zone E. Well #9 is the closest Landfill Well to Zone E and is known to capture groundwater emanating from the east side of the Municipal Landfill. For this reason, well #9 was used to provide data for characterization of the chemical composition of groundwater down gradient from the Municipal Landfill and assess the potential for hydraulic transport of contaminants from the northeast portion Municipal Landfill to the groundwater beneath Zone E.

A total of 21 VOCs were detected in groundwater samples collected from the Zone E Wells during Phase II monitoring. Nine of the 21 VOCs (chloromethane, chloroethane, 1,2-DCA, 1,2-dichloropropane, toluene, acrylonitrile, carbon disulfide, cis-1,3-dichloropropene, and 2-hexanone) were only detected in samples collected during the June 1995 sampling event.

Twenty of the 21 VOCs detected in Zone E Wells were detected in well MW-27S. Sixteen of the 21 VOCs detected in well MW-27S were also detected in well MW-19S, approximately 340 feet downgradient from Zone E. With the exception of acrylonitrile, each of the VOCs detected in well MW-19S was also detected in well MW-27S. Four VOCs (1,1-DCE, carbon tetrachloride, 1,2-DCA, and PCE) were above MTCA Method B formula values in well MW-27S during Phase II sampling (Table 3.19); and one VOC (1,1-DCE) was detected above the Method B formula value in well MW-19S (Figure 3-39).

Well EE-8 contained detectable levels of VOCs during only one sampling event (June 1995). Each of the seven VOCs detected in well EE-8 (1,2-DCA, chloromethane, toluene, acetone, carbon disulfide, 2-hexanone, and PCE) was below the laboratory quantification limit and was listed as an estimated concentration by the data validation team. None were detected above their Method B formula value.

In addition to the material present in Zone E, one potential source of VOCs in groundwater beneath Zone E is hydraulic transport of contaminants from a source area located in the eastern portion of the Municipal Landfill. Zone E is located directly south of the east side of the former Municipal Landfill. While the hydraulic gradient between Landfill Well #9 and Zone E Well MW-27S indicates flow to the southwest (Figures 3-6 through 3-16), no groundwater monitoring wells or landfill gas probes exist in the area adjacent to the eastern portion of the landfill (directly north of Zone E) to provide hydrostatic potential or chemical data from this area. However, 20 of the 21 VOCs detected in Zone E Wells during Phase II sampling were also detected in Landfill Wells; 18 of the 21 were detected in landfill gas samples; and 17 of the 20 VOCs detected in well MW-27S were also detected in Landfill Well #9.

Given the extent of VOC-impacted groundwater present along the northwestern boundary of the Municipal Landfill, the unknown volume and location(s) of contaminant source areas within the Municipal Landfill, and the similarity in VOCs detected in wells #9 and MW-27S, the potential for hydraulic transport of VOCs or migration of a dense vapor plume from the northeastern portion of the Municipal Landfill appears to warrant evaluation. The following section provides a discussion of each of the 21 VOCs detected in groundwater from Zone E Wells, the frequency of detection and range of concentrations observed, and comparisons between the distributions of VOCs in Zone E, Landfill, and background wells.

Six chlorinated ethenes (PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride) were detected in Zone E Wells during Phase II sampling. Two of the six (PCE and 1,1-DCE) were detected in excess of MTCA Method B formula values (Table 3.19). The distributions of chlorinated ethenes in groundwater surrounding Zone E are as follows:

- PCE was detected in Zone E Well MW-27S and Landfill Well #9 during all Phase II sampling events and in well MW-19S during three of the five sampling events. PCE was only detected in one sample from well EE-8 (June 1995). PCE exceeded the Method B formula value in three of the five samples collected from MW-27S during

Phase II sampling, but did not exceed the Method B formula value in any of the samples collected from MW-19S. PCE exceeded the Method B formula value in all Landfill Wells including well #9 during every Phase II sampling event.

PCE concentrations in well MW-27S ranged from 0.71 µg/L to 1.1 µg/L. PCE in Landfill Well #9 ranged from 1.9 µg/L to 3.5 µg/L. Well #9 was removed from the groundwater sampling program following the March 1996 sampling event as part of the revised post-remedial investigation monitoring program (Table 2.7). As a result, no data from this well is available for the 2nd quarter 1996. However, PCE was detected at the same concentration in well MW-27S (1.1 µg/L) during July 1996 as in the previous sampling event. PCE concentrations in well #9 exceeded 1.1 µg/L during the previous four quarters and would therefore be expected to exceed 1.1 µg/L during July 1996 as well. As can be seen in Table 3.18, the concentrations of PCE in Landfill Well #9 were higher than those observed in all Zone E Wells during every sampling event, indicating a potential source in the Municipal Landfill.

- TCE was detected in Zone E Wells MW-27S and MW-19S, as well as Landfill Well #9, in four of the five sampling events. TCE was not detected in wells MW-19S or MW-27S during July 1996 (well #9 has not been sampled since March 1996). TCE was not detected in any samples from well EE-8.

As can be seen in Table 3.18, the concentrations of TCE in Landfill Well #9 exceeded those measured in well MW-27S during every sampling event. TCE concentrations in well #9 ranged between 0.94 µg/L to 2.3 µg/L, while TCE concentrations in well MW-27S ranged between 0.24 µg/L and 0.58 µg/L. As with PCE, the lowest TCE concentrations measured in well #9 (0.94 µg/L in June 1995) exceeded the highest concentrations measured in MW-27S (0.58 µg/L in September 1995), indicating a potential source in the Municipal Landfill.

TCE concentrations in well #9 exceeded or equaled TCE concentrations in well MW-19S in all but one sampling event (September 1995), while TCE concentrations in well MW-19S exceeded those measured in well MW-27S during every sampling event. These results indicate that TCE in MW-19S is the result of hydraulic transport from the Municipal Landfill and is not associated with Zone E. These data also provide supporting evidence for hydraulic transport of TCE from a source in the northeast portion of the Municipal Landfill as a source of TCE in MW-27S.

- Cis-1,2-DCE was detected in Zone E Well MW-19S and Landfill Well #9 during the June 1995, December 1995, and March 1996 sampling events, but was only detected once (June 1995) in Zone E Well MW-27S. However, cis-1,2-DCE concentrations in well #9 exceeded the concentrations measured in both MW-27S and MW-19S during each of the three sampling events indicating a potential source in the Municipal Landfill. Trans-1,2-DCE was not detected in any Zone E Wells during Phase II sampling, but was detected in Landfill Well #9.
- 1,1-DCE (a biotransformation product of PCE, TCE, cis-1,2-DCE, and trans-1,2-DCE; Figure 3-25) was not detected in any samples from Landfill Well #9. The compound 1,1-DCE was detected in both Zone E Wells MW-19S and MW-27S during every sampling event with the exception of the December 1995 sample from

well MW-27S. The compound 1,1-DCE exceeded the Method B formula value in each of the five samples collected from MW-19S and two of the five samples collected from MW-27S during Phase II sampling. In addition, the concentrations of 1,1-DCE in MW-19S exceeded those measured in MW-27S during each of the five sampling events. As with TCE, these results indicate that the presence of 1,1-DCE in MW-19S is the result of hydraulic transport from the Municipal Landfill and is not associated with Zone E. The data also support hydraulic transport from the Municipal Landfill as the source of 1,1-DCE in MW-27S.

- Vinyl chloride (another biotransformation product of PCE, TCE, cis-1,2-DCE, and trans-1,2-DCE) was not detected in any Zone E Wells, but was detected in Landfill Well #9 during the March 1996 sampling event.

The concentrations of PCE, TCE, and their biotransformation products were consistently higher in Landfill Well #9 than in the Zone E Wells. Well #9 is the closest Landfill Well to Zone E and is known to capture groundwater emanating from the east side of the former Municipal Landfill. Well #9 provides data for characterization of the chemical composition of groundwater from the former Municipal Landfill and assessing the potential for hydraulic transport of contaminants from the northeastern portion of the former Municipal Landfill to groundwater beneath Zone E.

The consistently higher concentrations of PCE, TCE and their biotransformation products in Landfill Well #9 indicate that the presence of these chlorinated ethenes in groundwater is the result of hydraulic transport from sources located in the northeast portion of the Municipal Landfill and is not related to Zone E. The higher TCE and 1,1-DCE concentrations found in MW-19S as compared with MW-27S are also inconsistent with hydraulic transport from Zone E, and indicate a source in the Municipal Landfill.

Four chlorinated ethanes (1,1,1-TCA, 1,2-DCA, 1,1-DCA, and chloroethane) were detected in Zone E Wells during Phase II sampling. The distribution of chlorinated ethanes in groundwater surrounding Zone E can be described as follows:

- 1,1,1-TCA was detected in all samples collected from wells MW-19S and MW-27S from June 1995 through March 1996 with the exception that 1,1,1-TCA was not detected in MW-27S during the June 1995. The concentrations of 1,1,1-TCA in well MW-19S exceeded those measured in MW-27S during each sampling event. These results indicate that 1,1,1-TCA in MW-19S is not associated with Zone E and that its presence in MW-27S may also be the result of hydraulic transport from the Municipal Landfill.

- The compound 1,2-DCA was only detected in Zone E Wells EE-8, MW-19S, and MW-27S during one sampling event (June 1995); 1,2-DCA concentrations in the Zone E wells ranged between 0.22 and 0.6 µg/L (Table 3.18). As noted earlier, 1,2-DCA was detected in 32 of the 39 wells sampled across the site during June 1995, including Landfill Well #9 and upgradient background wells MW-20S, MW-28S, and NW-5. For this reason the presence of 1,2 DCA does not appear to be related to a source in Zone E.
- 1,1-DCA was detected in Zone E Wells MW-19S and MW-27S, and Landfill Well #9 during three sampling events (June 1995, September 1995, and March 1996). The concentrations of 1,1-DCA measured in wells MW-19S and MW-27S ranged from 0.054 µg/L to 0.29 µg/L. The concentrations of 1,1-DCA in well #9 ranged from 0.36 µg/L to 0.55 µg/L, with the concentrations of 1,1-DCA in well #9 exceeding those measured in wells MW-19S and MW-27S during each of the three sampling events. As can be seen in Table 3.18, the lowest concentrations measured in well #9 during these three events exceeded the highest concentrations measured in MW-19S or MW-27S.

The compound 1,1-DCA was not detected in MW-19S and MW-27S, but was detected in well #9 during the December 1995 and July 1996 sampling events. In addition, the concentrations of 1,1-DCA, when detected in well MW-19S, consistently exceeded those measured in MW-27S. Together, these results indicate that the source of 1,1-DCA in wells MW-19S and MW-27S is associated with an upgradient source in the northeastern portion of the Municipal Landfill and is not related to Zone E.

- Chloroethane was detected in Zone E Wells MW-19S and MW-27S during only one sampling event (June 1995). Chloroethane was also detected in upgradient background wells MW-28S and NW-5 during this same event. The concentrations ranged from a low of 0.58 µg/L in well MW-27S to a high of 1.3 µg/L in well MW-19S. The higher concentrations found in MW-19S are not consistent with a source in Zone E. However, each of the detected concentrations was flagged as an estimated value by the data validation team and, as a result, conclusions relating to direct comparisons between these values may be inappropriate. Chloroethane was not detected in any Zone E Wells during any subsequent sampling events, but was detected in Landfill Well #9 during September 1995 and March 1996 and in background well MW-28S during December 1995. Based on these results, the presence of chloroethane in groundwater does not appear to be related to Zone E.

Five chlorinated methanes [trichlorofluoromethane, carbon tetrachloride (tetrachloromethane), chloroform (trichloromethane), methylene chloride (dichloromethane), and chloromethane] were detected in groundwater samples from Zone E Wells. Their distributions in groundwater surrounding Zone E are as follows:

- Trichlorofluoromethane was detected in Zone E Well MW-27S during four consecutive sampling events (June 1995 through March 1996) and in well MW-19S during three consecutive events (September 1995 through March 1996). Trichlorofluoromethane was also detected in the June 1995 and March 1996 samples from Landfill Well #9, but was not detected in any samples from Zone E Well EE-8.

The highest trichlorofluoromethane concentrations occurred in well MW-27S during June 1995 and March 1996, although the concentrations measured in MW-19S exceeded those in MW-27S during September and December 1995. These results are inconclusive although they provide some evidence for a source in the landfill.

- Carbon tetrachloride was only detected in one sample from Zone E Wells: the March 1996 sample from well MW-27S. Chloroform was detected in well MW-19S during June 1995, September 1995, and March 1996 and in well MW-27S during June 1995, September 1995, and December 1995. Neither carbon tetrachloride nor chloroform were detected in any samples from Zone E Well EE-8 or Landfill Well #9.

Carbon tetrachloride was only detected once in MW-27S, and therefore it is not possible to draw conclusions regarding the potential source. The results for chloroform are also inconclusive, although the occurrence of chloroform in MW-19S at concentrations exceeding MW-27S in June and September 1995, as well as its presence in MW-19S during March 1996 when it was not detected in MW-27S, is not consistent with a source in Zone E.

- Methylene chloride was detected in wells MW-19S and MW-27S, as well as upgradient wells MW-20S and MW-28S, during the June 1995 sampling event. Methylene chloride concentrations in upgradient wells MW-20S and MW-28S (0.48 and 0.73 µg/L, respectively) exceeded the concentrations observed in MW-19S and MW-27S (0.2 and 0.23 µg/L, respectively) during June 1995; however, each of the detected concentrations was flagged as an estimated value making direct comparisons between the measured values somewhat inappropriate.

Methylene chloride was only detected in the Zone E Wells during one other sampling event (1.1 and 1.5 µg/L in wells MW-27S and MW-19S, respectively, during March 1996). The higher concentrations found in MW-19S are not consistent with a source in Zone E. However, each of these concentrations was also flagged as an estimated value by the data validation team so that a direct comparison of concentrations may not be appropriate. Methylene chloride was not detected in any samples from well EE-8.

- Chloromethane was detected in all Zone E Wells, as well as Landfill Well #9, and upgradient background wells MW-20S, MW-28S, and NW-5 in June 1995, but was not detected in any of these wells during subsequent sampling events indicating that its presence is not related to Zone E.

Based on the analysis of data for chlorinated methanes, it appears that the presence of methylene chloride and chloromethane are not related to Zone E, but may be related to an

upgradient source in the Municipal Landfill. Carbon tetrachloride, the only chlorinated methane above MTCA Method B formula values, was only detected in one sample; its source is unclear. The results for trichlorofluoromethane and chloroform are inconclusive, although they provide some evidence for a potential source in the Municipal Landfill.

Two ketones (acetone and 2-hexanone) were detected in groundwater samples from the Zone E Wells. All but two detections (acetone in wells MW-19S and MW-27S) occurred during the June 1995 sampling event. Each of the detections was well below MTCA Method B formula values. Ketone distributions in Zone E groundwater can be described as follows:

- Acetone was detected in Zone E Well EE-8 during the June 1995 sampling event and in wells MW-19S and MW-27S during June and September 1995. Acetone was also detected in upgradient wells MW-20S, MW-28S, and NW-5 during June 1995, indicating that its presence in groundwater is not associated with Zone E.
- The compound 2-hexanone was detected in Zone E Wells EE-8 (0.15 µg/L), MW-19S (0.037 µg/L), and MW-27S (0.23 µg/L) during the June 1995 sampling event, but was not detected in any Zone E Wells during any subsequent sampling events. The compound 2-hexanone was also detected in Landfill Well #9 (0.17 µg/L) during June 1995 indicating that its presence in groundwater is not associated with a source in Zone E.
- Benzene and toluene were each detected in groundwater from the Zone E Wells during the June 1995 sampling event, but were not detected during subsequent sampling events. Each of the detections was well below the MTCA Method B formula values. Benzene was detected at 0.03 µg/L in well MW-27S during the June 1995 sampling event, but was also detected at 0.3 µg/L in Landfill Well #9 and at 0.4 µg/L in upgradient background well MW-28S, indicating its presence is not associated with Zone E.

Likewise, toluene was detected in Zone E Wells EE-8 and MW-27S during June 1995, but was detected at higher concentrations in upgradient wells MW-20S, MW-28S, and NW-5, as well as Landfill Wells #9 during this same event. Toluene was not detected in any of these wells during subsequent sampling events. These results indicate that the source of benzene and toluene in groundwater is not associated with Zone E.

Four additional VOCs (acrylonitrile, cis-1,3-dichloropropene, 1,2-dichloropropane, and carbon disulfide) were detected in groundwater samples from the Zone E Wells. Acrylonitrile and cis-1,3-dichloropropene were each detected in only one sample: the June 1995 samples from wells MW-19S and MW-27S, respectively. The compound 1,2-dichloropropane was detected in

samples from MW-19S and MW-27S during June 1995. However, 1,2-dichloropropane concentrations in Landfill Well #9 exceeded those measured in MW-19S and MW-27S during June 1995. The compound 1,2-dichloropropane was not detected in any Zone E Wells during any subsequent sampling events, but was detected in Landfill Well #9 during September 1995, December 1995, and March 1996, indicating that its presence in groundwater is not associated with Zone E.

Carbon disulfide was detected in two samples: the June 1995 samples from Zone E Wells EE-8 and MW-27S. Carbon disulfide concentrations were measured at 0.021 µg/L in well MW-27S and at 0.27 µg/L in well EE-8, but were also measured at 0.05 and 0.035 µg/L in upgradient wells MW-20S and MW-28S, respectively, during June 1995. Each of these concentrations was flagged as an estimated concentration by the data validation team. Carbon disulfide was not detected in any other samples from Zone E Wells, but was detected in Landfill Well #9 and upgradient well MW-20S during March 1996. Likewise, carbon disulfide was detected at 0.028 and 1.1 µg/L in wells EE-6 and EE-7, respectively, during March 1996, but was also detected at 0.069 and 0.033 µg/L in Landfill Wells #8 and #9, respectively, and at 0.027 µg/L in upgradient well MW-20S. These results indicate that the presence of carbon disulfide in groundwater is not associated with Zone E. The source of acrylonitrile and cis-1,3-dichloropropene is unknown.

In summary, of the 21 VOCs detected in Zone E Wells, all but six (1,1-DCE, 1,1,1-TCA, carbon tetrachloride, chloroform, trichlorofluoromethane, cis-1,3-dichloropropene, and acrylonitrile) were consistently detected at higher concentrations in either Landfill Well #9 or upgradient background wells MW-20S, MW-28S, or NW-5, indicating that their presence in groundwater is not associated with Zone E. The compound 1,1-DCE (a biotransformation product of PCE and TCE) was not detected in Landfill Well #9. However, both PCE and TCE were detected in all thirteen Landfill Wells during each of the Phase II sampling events, indicating that 1,1-DCE may also be related to a potential source area in the Municipal Landfill. The concentrations of 1,1,1-TCA detected in well MW-19S exceeded those measured in upgradient well MW-27S during each sampling event, indicating that its presence in groundwater is also not associated with Zone E.

The results for trichlorofluoromethane and chloroform are inconclusive, although they provide some evidence for a potential source in the Municipal Landfill. Neither compound was

detected above MTCA Method B formula values. Carbon tetrachloride, cis-1,3-dichloropropene, and acrylonitrile were only detected in one well and during only one sampling event. As a result, it is not possible to draw conclusion regarding their source in groundwater.

3.6.4.2 SEMI-VOLATILE ORGANIC COMPOUNDS

Well MW-27S was the only Zone E Well that contained detectable levels of SVOCs during Phase II sampling. A total of three SVOCs (hexachloroethane, naphthalene, and di-n-butyl phthalate) were detected in MW-27S (Table 3.20). Each of the three compounds was only detected once during Phase II sampling. Hexachloroethane and naphthalene were detected in the June 1995 samples from well MW-27S. Di-n-butyl phthalate was detected in the September 1995 sample from well MW-27S. Data validation results indicate that di-n-butyl phthalate was also detected in the method blank for this sample.

The concentrations of all three SVOCs detected in wells MW-27S were well below the MTCA Method B formula values for the respective compounds. These results indicate that Zone E is not acting as a significant source of SVOCs to groundwater.

3.6.4.3 HEXAVALENT CHROMIUM AND MERCURY ANALYSES

As discussed in Section 2.6.4, a review of the site history indicates that chlor-alkali process wastes were placed in Zone E. In addition, the results of the Bulk Waste Characterization Study indicated the presence of mercury in waste samples from Zone E. As a result, groundwater monitoring wells EE-8, #9, MW-19S, MW-20S, and MW-27S were sampled for mercury on March 24 and 25, 1996. No mercury was detected in any of the samples collected.

As discussed in Sections 2.6.1 and 3.6.1 above, an apparent conductivity anomaly was observed in the EM-31 survey data collected from the central portion of Zone TS-1/SL-1. In addition, groundwater sampling results indicated elevated levels of chromium in Zone E monitoring wells EE-8 and MW-19S, downgradient from Zone TS-1/SL-1.

The highest concentrations of chromium occurred in wells EE-8 and MW-19S, southwest of Zone E. Chromium levels in EE-8 ranged from 68.3 µg/L to 343 µg/L during Phase II

sampling events. Chromium concentrations in well MW-19S ranged from less than detection limits in March 1996 to 653 $\mu\text{g/L}$ during September 1995. As a result, wells EE-8 and MW-19S were sampled for hexavalent and total chromium on March 26, 1996. Each well was also sampled for total chromium on March 25, 1996, as part of the site quarterly monitoring program.

Unfortunately, the results of the March 25 and March 26, 1996 sampling did not provide any additional insight in determining the source of chromium in wells EE-8 and MW-19S. No hexavalent chromium was detected in either well. Total chromium was also below detection limits (50 μl and 7.9 μl) in MW-19S for both sets of samples. Total chromium was detected at 79.2 μl in EE-8 in the March 25, 1996, sample, but was below detection limits (50 μl) in the sample collected on March 26, 1996. The MTCA Method B formula values for hexavalent chromium in groundwater is 80 μl . There is no established Method B cleanup level for total chromium.

3.7 ZONES C AND D AND THE EAST-WEST BURN TRENCH

3.7.1 GEOPHYSICAL INVESTIGATION, ZONES C AND D

3.7.1.1 EM-31 AND GROUND MAGNETICS

The EM-31 apparent conductivity data from Zones C and D (Figure 3-40) provide excellent definition of the former bulk liquid disposal ponds in the form of two elevated conductivity anomalies. These anomalies generally match the closure survey with the exception that Zone D appears to extend approximately ten feet east of the closure survey boundary.

The magnetic and in-phase EM-31 data (Figure 3-41, Figure 3-42, and Figure 3-43) exhibit a single small anomaly, potentially indicating the presence of a buried metallic object near the northeast corner of Zone D. A strong magnetic anomaly is also evident south of Zones C and D (Figure 3-41 and Figure 3-42). This anomaly is not evident on the EM-31 maps (Figure 3-40 and Figure 3-46) and may be due to the presence of ferro-magnesian minerals in the basaltic cobbles used in construction of an old road formerly located south of Zones C and D (Larry Dietrich, personal communication, 1992).

The former east-west burn trenches (BT-1 trenches) are clearly defined by EM-31 and magnetic anomalies (Figure 3-40 through 3-43). The northern-most BT-1 trench, centered on grid

line 175 north, appears to extend eastward to the approximate closure boundary of Zone C. The southern trench is not as clearly defined, but appears to be centered approximately on grid line 50 feet north and extends approximately 40 feet south-southwest of Zone C.

3.7.1.2 EM-34 SURVEY

Both the 10- and 20-meter HDM EM-34 data clearly show the outline of the former bulk liquid disposal ponds (Figure 3-44 and Figure 3-45) and correlate well with the EM-31 data. A general increase in apparent conductivity can be observed trending from northeast to southwest across the survey area in the 40-meter HDM data (Figure 3-46), although it is not clear if this is related to Zones C and D or some other phenomenon (e.g., regional geologic increases).

The individual disposal cells of Zones C and D are clearly expressed as negative anomalies in the 10-meter coil separation VDM data (Figure 3-47). A similar, but more subdued conductivity anomaly is observed in the 20-meter and 40-meter VDM data (Figure 3-48 and Figure 3-49). A discussion of the effects of variations in coil orientation (VDM vs. HDM) and coil separation distances and their applications in EM-34 surveys is provided in Appendix E.

A qualitative examination of the EM-34 data provides some evidence of a shallow zone of slightly increased soil conductivities extending to the southwest from Zone C, and appears to broaden with depth (Figure 3-47 and Figure 3-48). This broadening with increasing depth indicates that diffusion of conductive ions has occurred in the vadose zone down and away from the pond residues towards the southwest.

The evidence for a southwest-trending conductivity zone is not as clear in the deeper soil conductivity data collected using 40-meter coil separations. EM-34 data represent a summation of conductivity measurements from the surface to the maximum investigative depth for the instrument. Thus, the results of the EM-34 investigation implies that the area of increased soil conductivities beneath Zones C and D does not extend significantly below the maximum investigative depth for the 20-meter VDM EM-34 instrument (approximately 50 feet bgs).

3.7.2 BULK WASTE CHARACTERIZATION, ZONES C AND D

The results of the bulk waste characterization activities indicate that both Zones C and D are fully covered by vegetated soil caps and plastic liners. As noted in Section 2.7.2, the plastic cover in each zone was found immediately overlying the waste under a vegetated soil cap approximately three feet thick. The material in Zone C was multicolored and stratified, ranging from purple to yellow in color, and was generally hard and dry. The material in Zone D was also multicolored and stratified and ranged from hard to rubbery in consistency.

VOCs and heavy metals were detected in the soil sample from immediately beneath Zone C (Table 3.21), although only barium was detected in the TCLP extract from Zone C samples. No soil samples were collected from beneath Zone D because soil was not encountered during excavation activities.

Waste profile analyses indicate that the material present in Zones C and D is not corrosive, flammable, or reactive. Screening tests were negative for sulfides, cyanides, phenolics, hexavalent chromium, chlorinated compounds, and oxidizers. The results of the TCLP tests were negative for heavy metals, pesticides, and TC Organics, with the exception of 1,2-DCA in material from Zone D (Table 3.22). The results of the fish bioassay tests for Zones C and D material were negative, with no mortalities in the test organisms in either 10 ppm or 100 ppm concentrations (Appendix I).

The materials are not subject to RCRA listed waste codes in the F- or K-code series, as these are process-specific waste codes. The U- and P-code series are also not applicable, as these codes apply to discarded commercial chemical products. The source of the materials cannot be verified in a manner that allows designation of the materials per these listed waste codes.

To provide information on administrative feasibility and costs for different remedial options during the feasibility study, the materials were evaluated pursuant to RCRA. Based on this information, the material in Zone C would not be designated, if excavated, as either a characteristic RCRA hazardous waste or as a characteristic Washington State Dangerous Waste, and does not pose a threat to human health and the environment. However, due to the level of 1,2-DCA present in the TCLP extract, at least a portion of the material from Zone D, if

excavated, would be designated as both a D028 RCRA hazardous waste and a Washington State Dangerous Waste.

3.7.3 SOIL CHEMISTRY, ZONES C AND D

According to historical records, the materials deposited in Zones C and D consist of approximately 3.5 million gallons of bulk liquids, including chromium plating wastes, cutting oils, metal cleaning and finishing wastes, paint and solvent waste, plywood resins, and lime sludge. Soil samples were collected from borings B-01, B-02, and MW-18S during the Phase I investigation and analyzed for VOCs, SVOCs, and priority pollutant metals. Soil from MW-18S was also analyzed for pesticides/herbicides. The results of the Phase I analyses are summarized as follows:

- no herbicides or pesticides were detected in MW-18S;
- low levels of di-n-butyl phthalate, hexachlorobenzene, and hexachloroethane were detected in samples submitted for SVOC analyses;
- all priority pollutant metals were at or below site background levels; and
- acetone, methylene chloride, toluene, and 2-hexanone were detected in samples submitted for VOC analyses.

Soil boring B-01 (Figure 2-11) was installed in the location of the EM-34 conductivity anomaly during the Phase I field investigation. Soil samples were collected from boring B-01 at depths of 11, 26, 41, and 60 feet bgs and analyzed for SVOCs, PCBs, VOCs, and priority pollutant metals. None of the constituents were detected at levels above their respective MTCA Method B formula values.

Two additional borings (B-19 and B-20) were installed on May 15 and 16, 1996, during the Phase II field investigation, to further assess the soil beneath Zones C and D for the presence of VOCs and their potential for impacting groundwater. A summary of VOCs detected in borings B-19 and B-20 is provided as Table 3.23. Soil collected during the Phase II investigation indicated that six VOCs (acetone, 2-butanone, 4-methyl-2-pentanone, toluene, m,p-xylenes, and o-xylenes) were present in soil beneath Zone D. Four of these compounds (acetone, 2-butanone, 4-methyl-2-pentanone, and toluene) were also present in soil beneath Zone C.

As can be seen in Table 3.23, m,p-xylenes and o-xylenes were only detected in the uppermost sample from beneath Zone D. No xylenes were detected in soil from beneath Zone C. Similarly, toluene was only detected in the samples from 11 and 16 feet bgs, and 14 and 16 feet bgs in soil from beneath Zones C and D, respectively. No toluene or xylenes were detected in soil from beneath Zone C or D below approximately 16 feet bgs.

The compound 4-methyl-2-pentanone was detected in the sample from 11 ft bgs in Zone C soil and in samples from 14, 16, 26, and 36 feet bgs beneath Zone D.

Acetone and 2-butanone were the only VOCs detected below 35 feet bgs. Acetone was detected in all soil samples collected from both borings B-19 and B-20, while 2-butanone was detected in all soil samples collected from boring B-19 (Zone D) and all samples above 56 feet bgs in B-20 (Zone C). Concentrations of acetone and 2-butanone generally increase with depth to about 25-35 feet bgs with concentrations generally decreasing below 35 feet bgs.

Each of the six VOCs detected in borings B-19 and B-20 was well below its respective Method B formula value in all samples.

3.7.4 GROUNDWATER CHEMISTRY, ZONES C AND D

3.7.4.1 VOLATILE ORGANIC COMPOUNDS

Table 3.24 contains a summary of VOCs detected in wells #8, #9, EE-6, EE-7, MW-18S 20S, MW-27S, MW-28S, and NW-5 during Phase II sampling. Wells EE-6, EE-7, and MW-18S were designated as Zone C and D Monitoring Wells and were used for assessing groundwater conditions in the vicinity of Zones C and D. Wells #8 and #9 were used to provide data for use in characterizing the chemical composition of groundwater down gradient from the former Municipal Landfill and assessing the potential for hydraulic transport of contaminants from the former Municipal Landfill. Data from wells MW-28S and NW-5 were evaluated to assess contaminants in background wells upgradient from Zone C and D.

Six VOCs (acetone, 2-butanone, 4-methyl-2-pentanone, toluene, m,p-xylenes, and o-xylenes) were detected in soil samples collected from beneath the zones in borings B-19 and B-20. None of the six VOCs detected in borings B-19 and B-20 were present above their respective MTCA Method B formula values. Three VOCs (1,2-DCA, 2-butanone, and TCE)

were detected in the TCLP analysis of material from Zone D. One of these (2-butanone) was also detected in the TCLP analysis of material from Zone C; 2-butanone was the only VOC detected in the TCLP extract that was also detected in borings B-19 and B-20.

It is unknown whether the TCE detected in the material in Zone D was present as a primary waste product or formed as a biotransformation product of PCE degradation. However, neither PCE nor any other potential biotransformation products (cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride) were detected in any of the soil samples from beneath the zones or samples of the material collected from Zones C and D, indicating that TCE may have been present as a primary waste. Based on these results, it does not appear that the soil or material present in Zones C and D are acting as sources of 1,1-DCE or PCE in groundwater.

Zones C and D are located adjacent to, and hydraulically downgradient from, the southern boundary of the Municipal Landfill and hydraulic transport of VOCs in groundwater migrating from the Municipal Landfill is a potential source of VOCs in groundwater beneath Zones C and D. A total of 20 VOCs were detected in groundwater samples collected from the Zone C and D Wells during Phase II monitoring. Each of the 20 VOCs detected in Zone C and D Wells during Phase II sampling was also detected in Landfill Wells; 18 of the 20 were detected in landfill gas and all but 5 of the 20 [1,1-DCE, 2-butanone (MEK), m,p-xylenes, o-xylenes, and acrylonitrile] were detected in upgradient Landfill Wells #8 or #9. MEK, m,p-xylenes, and o-xylenes were not detected in upgradient Landfill Wells #8 or #9, but were detected in soil samples from borings B-19 and B-20. MEK was the only one detected below approximately 15 ft bgs (Table 3.23).

Two compounds (PCE and 1,1-DCE) were detected above MTCA Method B formula values (Table 3.25) in Zone C and D Wells. The compound 1,1-DCE, a biotransformation product of PCE and TCE, exceeded the MTCA Method B formula value once: the September 1995 sample from well MW-18S. PCE and TCE were both detected in all three Zone C and D Wells and all thirteen Landfill Wells during each of the five Phase II sampling events. PCE exceeded Method B concentrations in all Zone C and D and Landfill Wells (Figure 3-50 during every Phase II sampling event.

The following section provides a discussion of the frequency of detection and range of concentrations observed in each of the 21 VOCs detected in groundwater from Zone C and D

Wells, along with comparisons between the distributions of VOCs in Zone C and D, Landfill, and background wells.

Six chlorinated ethenes (PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride) were detected in Zone C and D Wells during Phase II sampling (Table 3.24). Their distributions in groundwater surrounding Zones C and D are as follows:

- PCE and TCE were detected in all Zone C and D and Landfill Wells analyzed for VOCs during Phase II sampling. The concentrations of both PCE and TCE were consistently higher in upgradient Landfill Well #9 than in Zone C and D Wells, indicating an upgradient source in the Municipal Landfill. Zone C and D Wells EE-6 and MW-18S and Landfill Well #9 were removed from the groundwater sampling program as part of the revised post-remedial investigation monitoring program (Table 2.7) initiated in the 2nd quarter 1996. However, PCE was detected at similar concentrations in both Zone C and D Well EE-7 (1.1 µg/L) and upgradient Landfill Well #8 (0.9 µg/L) during this sampling event. These data are consistent with earlier results and provide supporting evidence for an upgradient source. TCE was not detected in either well during the 2nd quarter 1996 sampling event.
- Cis-1,2-DCE was detected in all Zone C and D Wells and upgradient Landfill Wells #8 and #9 during the June 1995, September 1995, and March 1996 sampling events. Trans-1,2-DCE was not detected in any Zone C and D Wells, but was detected in wells #8 and #9 during the June 1995, September 1995, and March 1996 sampling events. Cis-1,2-DCE concentrations were consistently higher in Landfill Wells #8 and #9 than all Zone C and D Wells with the exception of the June 1995 sampling event. As in the other sampling events, cis-1,2-DCE concentrations in Landfill Wells #8 and #9 exceeded the concentrations measured in Zone C and D Wells EE-6 and EE-7 during the June 1995 sampling event. However, cis-1,2-DCE concentrations in well MW-18S southeast of Zones C and D exceeded the concentrations Landfill Wells #8 and #9 during the June 1995 sampling event.
- 1,1-DCE (a biotransformation product of PCE, TCE, cis-1,2-DCE, and trans-1,2-DCE) was not detected in upgradient Landfill Wells #8 and #9, but was detected in Zone C and D Well MW-18S during the June 1995, September 1995, and March 1996 sampling events. Conversely, vinyl chloride (another biotransformation product of PCE, TCE, cis-1,2-DCE, and trans-1,2-DCE) was not detected in any Zone C and D Wells, but was detected in Landfill Well #9 during the March 1996 sampling event.

The consistently higher concentrations of PCE, TCE, and their biotransformation products in upgradient Landfill Wells #8 and #9 indicate that the presence of these VOCs in groundwater beneath Zones C and D are the result of hydraulic transport from the Municipal Landfill.

Four chlorinated ethanes (1,1,1-TCA, 1,2-DCA, 1,1-DCA, and chloroethane) were detected in Zone C and D Wells during Phase II sampling. The distribution of chlorinated ethanes in groundwater surrounding Zone B can be described as follows:

- 1,1,1-TCA was only detected in one Zone C and D Well (MW-18S). The compound 1,1,1-TCA was detected in well MW-18S during the 2nd quarter 1995 through the 1st quarter 1996 sampling events. The compound 1,1,1-TCA was also detected in either upgradient Landfill Well #8 or #9 during each of these sampling events, with the exception of December 1995, but was not detected in any samples collected from wells EE-6 or EE-7.
- The compound 1,2-DCA was detected at concentrations ranging between 0.31 and 0.43 µg/L in Zone C and D Wells EE-6, EE-7, and MW-18S and Landfill Wells #8 and #9 during June 1995. As noted earlier, 1,2-DCA was detected in 32 of the 39 wells sampled across the site during June 1995, including upgradient background wells MW-28S, and NW-5. The compound 1,2-DCA was not detected in any other samples collected from Zone C and D Wells EE-6 or EE-7, but was detected at concentrations of 0.086 and 0.16 µg/L in samples collected from well MW-18S during September and December 1995, respectively.
- 1,1-DCA was detected in all Zone C and D Wells, as well as upgradient Landfill Wells #8 and #9, during the June 1995, September 1995, and March 1996 sampling events. The concentrations of 1,1-DCA in upgradient Landfill Wells #8 and #9 were higher than those measured in Zone C and D Wells during each of the three sampling events, indicating an upgradient source in the Municipal Landfill. The compound 1,1-DCA was not detected in any Zone C and D Wells during the December 1995 or July 1996 sampling events.
- Chloroethane was only detected in one Zone C and D Well (MW-18S). Chloroethane was detected in well MW-18S during June and December 1995. Chloroethane was also detected in upgradient background wells MW-28S and NW-5. Chloroethane was detected in upgradient well MW-28S during June and December 1995 and in well NW-5 during June 1995. Chloroethane was not detected in any Zone C and D Wells during either the September 1995 or March 1996 sampling events, but was detected in upgradient Landfill Well #9 during each of these sampling events.

Four chlorinated ethanes (1,1,1-TCA, 1,2-DCA, 1,1-DCA, and chloroethane) were detected in Zone C and D Well MW-18S and upgradient Landfill Well #9. Only two (1,2-DCA and 1,1-DCA) were detected in Zone C and D Wells EE-6 and EE-7. Both 1,2-DCA and 1,1-DCA were detected at higher concentrations in upgradient wells and do not appear to be related to Zones C and D. Wells EE-6 and EE-7 are located closer to and hydraulically downgradient from Zones C and D, and would therefore be expected to intercept any potential contaminants migrating from Zones C and D. Chloromethane and 1,1-TCA were not detected in wells EE-6

and EE-7, but were detected in well MW-18S and #9. Therefore, the presence of 1,1,1-TCA and chloroethane in well MW-18S does not appear to be related to Zones C and D, but may be the result of hydraulic transport from the Municipal Landfill (Figure 3-50).

Four chlorinated methanes [trichlorofluoromethane, chloroform (trichloromethane), methylene chloride (dichloromethane), and chloromethane] were detected in groundwater samples from Zone C and D Wells. Their distributions in groundwater surrounding Zone C and D are as follows:

- Trichlorofluoromethane was detected in only two samples from Zone C and D Wells: the September 1995 and December 1995 samples from well MW-18S (0.13 and 0.068 µg/L, respectively). Trichlorofluoromethane was not detected in any samples from Zone C and D Wells EE-6 or EE-7, but was detected in the June 1995 and March 1996 samples from upgradient Landfill Well #9.
- Chloroform was detected only once in groundwater from Zone C and D Wells: the June 1995 sample from well MW-18S (0.086 µg/L).
- Methylene chloride was detected in Zone C and D Wells during three consecutive sampling events (June, September, and December 1995). Methylene chloride was detected in Zone C and D Well MW-18S during June 1995, but was also detected in Landfill Well # 8 and upgradient background well MW-28S during this same event. The highest concentrations were observed in MW-28S. Methylene chloride was also detected in Zone C and D Well MW-18S in September 1995 and in well EE-7 in December 1995, but was not detected in Landfill Wells #8 or #9 during either of these events.
- Chloromethane was detected in all Zone C and D Wells, as well as Landfill Wells #8 and #9, with concentrations ranging between 0.17 and 0.29 µg/L. Each of the detections was flagged as an estimated value by the data validation team. Chloromethane was also detected in upgradient background wells MW-28S and NW-5 during June 1995. Chloromethane was not detected in any Zone C and D Wells or in wells #8 or #9 during any other sampling event.

As with chlorinated ethanes, four chlorinated methanes (trichlorofluoromethane, chloroform, methylene chloride, and chloromethane) were detected in Zone C and D Wells. Only two chlorinated methanes (methylene chloride and chloromethane) were detected in Zone C and D Wells EE-6 or EE-7 while each of the four VOCs were detected in well MW-18S. Again, wells EE-6 and EE-7 are located closer to and hydraulically downgradient from Zones C and D. For this reason, wells EE-6 and EE-7 would be expected to intercept any potential contaminants migrating from Zones C and D. Therefore, as with chlorinated ethanes, the

presence of chlorinated methanes in groundwater does not appear to be related to Zones C and D, but may be the result of hydraulic transport from the Municipal Landfill (Figure 3-50).

Three ketones (acetone, 2-butanone, and 2-hexanone) were detected in groundwater from Zone C and D Wells with all but one detection (acetone in well MW-18S) occurring during June 1995 (Table 3.23). Ketone distributions in Zone C and D groundwater can be described as follows:

- Acetone was detected in Zone C and D Wells during two sampling events (June and September 1995). Each of the detections was well below the MTCA Method B formula values for acetone. Acetone was detected in two Zone C and D Wells (MW-18S and EE-6) at concentrations ranging between 0.93 and 2.9 $\mu\text{g/L}$ during June 1995. However, acetone was also detected at 3.1 $\mu\text{g/L}$ in upgradient Landfill Well #9 and at concentrations of 0.78 and 4 $\mu\text{g/L}$ in upgradient background wells MW-28S and NW-5, respectively, indicating that its presence in groundwater was not associated with Zone C and D. Acetone was only detected in one other sample from the Zone C and D Wells: 0.84 $\mu\text{g/L}$ in the September 1995 sample from well MW-18S.
- The compounds 2-butanone and 2-hexanone were each detected in one sample from Zone C and D Wells (0.24 and 0.16 $\mu\text{g/L}$, respectively, in the June 1995 sample from well EE-7). Each was well below the MTCA Method B formula value. The compound 2-butanone was detected at similar concentrations (0.24 $\mu\text{g/L}$) in upgradient background well MW-28S during this same sampling event; 2-hexanone was detected at concentrations ranging between 0.15 and 0.17 $\mu\text{g/L}$ in samples from upgradient Landfill Wells #8 and #9, respectively, during June 1995.

The presence of acetone, 2-butanone, and 2-hexanone at similar concentrations in upgradient wells during the same sampling event that they were detected in Zone C and D Wells, indicate that their presence in groundwater is associated with an upgradient source in the Municipal Landfill.

Toluene, ethylbenzene, and xylenes were each detected in groundwater samples from Zone C and D Wells in June 1995. None of these compounds was detected in Zone C and D Wells during any subsequent sampling events. Each of the detections was well below the MTCA Method B formula values for toluene and xylenes. A description of their distributions in groundwater follows:

- Toluene was detected in all three Zone C and D Wells, as well as upgradient wells MW-28S and NW-5 and Landfill Well #9 during the June 1995 sampling event. The

highest toluene concentrations were observed in upgradient well NW-5 and Landfill Well #9 indicating that Zones C and D are not the source of toluene in groundwater.

- Ethylbenzene and xylenes were detected in Zone C and D Well EE-7 in June 1995, but were not detected in adjacent Landfill Wells #8 or #9. Each of these compounds was detected in the soil sample collected immediately beneath Zone C during Bulk Waste Characterization Activities (Table 3.23), although ethylbenzene was not detected in soil borings B-19 or B-20 (Figure 2-11). Xylenes were detected in the soil sample collected from 14 ft bgs in boring B-19, beneath Zone D, but was not detected in any other samples from B-19 or any samples from B-20. Although xylene concentrations in groundwater are below the MTCA Method B formula value, its presence in waste and soil samples from beneath the zones indicates a potential source in Zones C and D.

Two additional VOCs (acrylonitrile and carbon disulfide) were detected in groundwater samples from the Zone C and D Wells. Acrylonitrile was only detected in one sample from the Zone C and D Wells: the June 1995 sample from well MW-18S (0.058 µg/L). Carbon disulfide was detected in three samples: the June 1995 sample from MW-18S and the March 1996 samples from wells EE-6 and EE-7. Carbon disulfide was measured at 0.046 µg/L in Zone C and D Well MW-18S during June 1995, but was also measured at 0.05 and 0.035 µg/L in upgradient wells MW-20S and MW-28S, respectively, during June 1995. Likewise, carbon disulfide was detected at 0.028 and 1.1 µg/L in wells EE-6 and EE-7, respectively, during March 1996, but was also detected at 0.069 and 0.033 µg/L in Landfill Wells #8 and #9, respectively, and at 0.027 µg/L in upgradient well MW-20S during March 1996. All detections of acrylonitrile and carbon disulfide in Zone C and D Wells were below MTCA Method B formula values.

As with the ketones, the presence of carbon disulfide at similar concentrations in upgradient and Landfill Wells during the same sampling events as it was detected in Zone C and D Wells, indicate that its presence in groundwater is not associated with Zone C and D. Acrylonitrile was only detected once in groundwater in well MW-18S and was never detected in wells EE-6 or EE-7. Wells EE-6 and EE-7 are located closer to and hydraulically downgradient from Zones C and D and would be expected to intercept any potential contaminants migrating from Zones C and D. Since acrylonitrile was only detected in ground water once, it is not possible to determine its source. However, because it was never detected in wells EE-6 or EE-7, its presence in groundwater does not appear to be associated with Zones C and D.

In summary, each of the 20 VOCs detected in Zone C and D Wells during Phase II sampling was also detected in Landfill Wells; 18 of the 20 were detected in landfill gas. An evaluation of the location, timing, and concentration of each of the VOCs detected in the Zone C and D Wells indicates that their presence in groundwater is not associated with Zones C and D, but appears to be associated with hydraulic transport from the Municipal Landfill.

3.7.4.2 SEMI-VOLATILE ORGANIC COMPOUNDS

Three Zone C and D Wells (EE-6, EE-7, and MW-18S) were sampled for SVOCs during the Phase II investigation. A total of eight SVOCs (benzoic acid, 2-methyl naphthalene, dimethyl phthalate, 2,6-dinitrotoluene, di-n-butyl phthalate, butyl benzyl phthalate, bis(2-ethyl hexyl) phthalate, and di-n-octyl phthalate) were detected in groundwater samples from these wells (Table 3.26).

Of the eight SVOCs detected, butyl benzyl phthalate was the only compound detected in more than one well, or during more than one sampling event. Butyl benzyl phthalate was detected in the June 1995 samples from wells EE-6 and EE-7. Both detections were below the laboratory practical detection limit and were reported as estimated concentrations.

The concentrations of all eight SVOCs detected in Zone C and D Wells were well below the MTCA Method B formula values for the respective compounds, indicating that Zones C and D are not acting as a significant source of SVOCs to groundwater.

3.7.4.3 APPENDIX I METALS

A total of twelve WAC 173-351-990 Appendix I metals (antimony, arsenic, barium, chromium, copper, lead, manganese, nickel, thallium, selenium, vanadium, and zinc) were detected in groundwater samples collected from Zone C and D Wells. Of these, only two (arsenic and lead) were detected at concentrations exceeding their respective MTCA Method B formula values.

As discussed in Section 3.13.3 below, arsenic was detected in 191 out of a total of 219 samples collected across the site during the Phase I and II investigations and in all but 3 of the 110 samples collected between December 1995 and July 1996. Each of these detections was

above the MTCA Method B formula value. Two of the three samples which did not contain arsenic were from Zone C and D Wells: the September 1995 samples from wells EE-6 and MW-18S. As stated above, arsenic was detected above the MTCA Method B formula value in 14 of the 15 samples collected from upgradient background wells NW-5, MW-20S, and MW-28S, as well as in 26 of the 29 samples collected from Offsite Wells MW-29S through MW-42S, indicating that its presence in groundwater is not related to site activities.

Lead was detected in four samples collected from Zone C and D Wells: the September 1995 and March 1996 samples from wells EE-6 and MW-18S. Two samples (the September 1995 from both wells) exceeded the MTCA Method A formula value. However, lead was detected in all 42 wells sampled across the site during September and October 1995, including all upgradient, background, and offsite wells. Lead concentrations exceeded the MTCA Method A formula value in 19 of the 42 wells sampled during September and October 1995, including upgradient well NW-5, but were below detection limits for all wells sampled during December 1995.

The high degree of variability in the number and concentrations of lead detected in groundwater at the site, as well as its occurrence in upgradient and background wells over the course of Phase II sampling, indicates that its presence in groundwater is not the result of waste handling activities at the site.

3.8 ZONES U-1 AND TS-2

Zones U-1 and TS-2 are both clearly visible as minor anomalies in EM-31 terrain conductivity data generated during Phase I. Zone U-1, a former disposal pond which accepted small quantities of bulk liquids, is expressed as a minor anomaly east of Zone D on the terrain conductivity map of Zones C and D (Figure 3-40). Zone TS-2 is expressed as a minor anomaly extending south of the southwest corner of Zone E on the terrain conductivity map (Figure 3-35). Zone TS-2 is believed to represent a reported temporary storage area for chlor-alkali sludge that was later moved into the southern pond area within Zone E.

These areas were adequately characterized during the Phase I RI. No additional Phase II investigation activities were specified in the Enforcement Order. The results of the Phase I investigation activities indicate that these zones are not impacting groundwater.

3.9 LAGOONS SL-2 AND SL-3

Twelve subsurface soil samples were collected from borings B-07, B-08, and B-12 during the Phase I field work to investigate soil in the vicinity of former sewage lagoons SL-2 and SL-3. Each sample was analyzed for herbicides, pesticides/PCBs, radionuclides, SVOCs, and priority pollutant metals. Samples from B-07 were also analyzed for VOCs. The results of the Phase I analyses are summarized as follows:

- No herbicides or pesticides were detected in any SL-2 or SL-3 soil samples.
- All radionuclides were at or below site background concentrations.
- Concentrations of all priority pollutant metals were at or below site background levels with the exception of copper in LS-06 (13.6 mg/kg) and LS-09 (15.1 mg/kg). The MTCA Method B formula value for copper in soil is 2,960 mg/kg.
- Low levels of di-n-butyl-phthalate were detected in SVOC samples from B-07 and B-12. Each of these constituents was also detected in the method blank. Therefore, the results of these analyses are not considered representative of site conditions.
- Three VOCs (acetone, methylene chloride and toluene) were detected in samples from B-07. Each of these constituents was also detected in the method blank. Therefore the results of these analyses are not considered representative of site conditions.

These areas were adequately characterized during the Phase I RI. No additional Phase II scope of work was specified in the Enforcement Order. The results of the Phase I characterization of these zones indicate that they are not impacting groundwater. Soil sampling locations and a more complete discussion of analytical results of soil samples from sewage lagoons SL-2 and SL-3 are provided in the Phase I RI Report (Burlington Environmental, 1994).

3.10 SLUDGE MANAGEMENT AREA AND LANDSPREAD AREA

Twenty surface soil samples were collected from the Sludge Management Area (SMA) and Landspread Area (LSA) during the Phase I field investigation and analyzed for herbicides, pesticides/PCBs, radio-nuclides, SVOCs, and priority pollutant metals. The results of the Phase I analyses are summarized as follows:

- No herbicides or pesticides were detected in any SMA or LSA soil samples.
- Concentrations of all radionuclides were at or below natural site background levels.
- Arsenic, nickel, cadmium, chromium, and zinc were present at levels above site background levels in SMA soil, while copper was present in excess of site background concentrations in both SMA and LSA soil. The concentrations of each of these five metals was well below their respective MTCA Method B formula values.
- Low levels of di-n-butyl-phthalate, and butyl-benzyl-phthalate were detected in SMA samples submitted for SVOC analyses. Di-n-butyl-phthalate was also detected in the method blank. Therefore the results of these analyses are not considered representative of site conditions.

These areas were adequately characterized during the Phase I RI. No additional Phase II scope of work was specified in the Enforcement Order. The results of Phase I characterization activities indicate that these zones are not impacting groundwater. Soil sampling locations and a more complete discussion of analytical results of soil samples from the SMA and LSA are provided in the Phase I RI Report (Burlington Environmental, 1994).

3.11 ZONE B

3.11.1 GEOPHYSICAL INVESTIGATION, ZONE B

3.11.1.1 GROUND PENETRATING RADAR

The results of the Phase II GPR survey indicate the presence of a strong reflector at a depth of approximately two feet bgs across most of the survey area at Zone B. This reflector is thought to represent the polyethylene sheeting placed over the soil cover during closure. Due to its strong reflective nature, there is very little resolution of subsurface features below a depth of about two feet bgs. However, a subsurface reflection characteristic of a drum was observed at approximately six feet bgs in the southern portion of Zone B.

GPR data from Zone B indicate that variations in depth to the polyethylene liner (generally less than a foot) occur across the survey area. It is not clear whether they are the result of subsidence within the areas containing drummed waste, or to placement of the liner over an uneven surface during closure of the zones.

The presence of the plastic sheeting prevented assessment of the thickness of the soil cover over the zone. Likewise, evidence of subsidence of the soil cover overlying the zone could not be assessed. The GPR survey did, however, confirm the presence of the polyethylene cover which would inhibit infiltration of precipitation into the zone. Additional discussion of the results of the GPR survey, is included in Appendix E of this report.

3.11.1.2 EM-31 AND GROUND MAGNETICS SURVEY

The stacked drums in Zone B are marked by well-defined anomalies using both ground magnetics and EM-31 (Figures 3-51 through Figure 3-54). These anomalies closely match the reported boundaries of Zone B as defined in the closure survey of 1980. However, the data indicate an extension of the main anomaly that may represent an area of additional buried drums extending approximately 30 feet south from the closure survey boundary.

3.11.2 DRUMMED WASTE CHARACTERIZATION STUDY, ZONE B

The Enforcement Order for the Pasco Landfill site required completion of a Drummed Waste Characterization Study at Zones A and B. A phased approach was approved by Ecology during development of the work plan documents. The resulting study used various non-intrusive investigative techniques including GPR, EM, corrosivity, and self-potential surveys, as well as soil-gas sampling and analysis.

The findings of the non-intrusive drummed waste characterization study at Zones A and B, were submitted to Ecology in a Technical Memorandum dated January 31, 1996, with an addendum dated May 6, 1996. In a letter dated June 10, 1996, Ecology informed the PLP Group that the study had achieved the objectives outlined in the Agreed Order for both Zones A and B.

3.11.2.1 GEOPHYSICAL SURVEYS

Results of the EM and GPR surveys at Zone B are discussed in Section 3.11.1, above.

3.11.2.2 SOIL-GAS SURVEY

Results of the soil-gas survey at Zone B indicate slightly depressed oxygen concentrations accompanied by slightly elevated carbon dioxide concentrations in some locations (Table 3.27). In addition, only very low methane concentrations and no acid gas were present in the samples analyzed from Zone B. These results indicate that very little biodegradation is occurring in Zone B. There was no evidence of corrosive gas which might affect the life expectancy of the drums within Zone B.

3.11.2.3 CORROSIVITY SURVEY

Samples collected from the Phase II soil borings at Zone B were submitted to an offsite laboratory to measure resistivity in both as-received and water-saturated soil. The average resistivity for as-received soil was 55,000 ohm-cm (Table 3.28). The resulting corrosivity index ranged from 9 to 26, with an average of 14.5 (Table 3.29). Assuming a steel drum wall thickness of 0.104 cm (0.041 inches), this indicates that the drums may have been penetrated by pitting one to three years before the survey was completed in 1995 (i.e., between 1992 and 1994).

The average resistivity for water-saturated soil was about 6,900 ohm-cm. The corrosion index for water-saturated samples ranged from 14 to 29 with an average of 19. Again assuming a steel drum wall thickness of 0.104 cm (0.041 inches), this indicates that penetration of the drums may have occurred four to six years before the survey was completed in 1995 (i.e., between 1989 and 1991).

Since the distilled water used to saturate the samples should have an infinitely high resistivity, addition of the water to the soil should increase or leave unchanged the resistivity of the soil. However, in all cases, both at Zone A and Zone B, the resistivity of the soil decreased significantly with the addition of water. This indicates the presence of significant quantities of dissolved salts in the soil. The presence of dissolved salts would result in significantly greater corrosion during periods of heavy rain or other times of infiltration of water.

As discussed in Section 4.5.3.2, soil with resistivity below 2,000 ohm-cm is considered moderately corrosive, while soil with resistivity above 10,000 ohm-cm is considered significantly less corrosive. *In-situ* soil resistivity for Zone B ranged from 14,363 to 32,172

ohm-cm, with an average of 22,563 ohm-cm, indicating that the soil in the vicinity of Zone B is mildly corrosive.

A comparison between laboratory and *in-situ* resistivity indicates that laboratory resistivity results for Zone B soil are about 100 percent higher than *in-situ* resistivity results. This is typical for comparisons between laboratory and *in-situ* resistivity measurements. CCS has completed many corrosion surveys in the Tri-Cities region and indicated that the resistivity of the soil surrounding Zone B is typical of soil resistivity in the Tri-Cities area.

An evaluation of internal corrosion rates in the drums was conducted by comparing corrosion rates in the "Chem-Cor" and "Cor-Sur" database, for different materials believed to be present in Zone B drums based on the site history investigation completed as part of the Phase I RI. The results of this evaluation indicate corrosion rates in excess of 50 mils (0.050 inches) per year for 2,4-D in carbon steel drums, and MCPA-bleed corrosion rates of less than 20 mils (0.020 inches) per year. In addition, carbon steel, the type of drums typically used, is not recommended for 2,4-D and MCPA-bleed which comprise the majority of the drums in Zone B. Additional information regarding the corrosivity survey can be found in Appendix F.

3.11.2.4 SELF POTENTIAL SURVEY

The SP survey at Zone B indicated anomalies of a greater magnitude than those observed at Zone A (Section 3.12.2.4). The entire northern half of Zone B is characterized by negative anomalies of approximately 40 mV, with some readings in excess of 50 mV. These anomalies end abruptly, possibly indicating that corrosion of buried drums is the source of the high SP readings. Based on the assumption that a single drum corroding is generating the 50 mV anomaly, and that corrosion has been occurring at the same rate consistently over time, the drum would be approximately 10 percent corroded.

Small SP anomalies were also observed in the southern portion of Zone B. The southeastern portion of the zone had positive anomalies greater than 20 mV. It is possible that this area serves as an anode for the northern area. Other anomalies seen in the southern portion of the zone are likely due to the down slope topography and precipitation during the May 1995 field work. Additional information regarding the SP survey can be found in Appendix G.

3.11.3 SOIL CHEMISTRY, ZONE B

As part of the Phase I field investigation, subsurface soil samples were collected from borings B-05 and B-06 to assess potential soil contamination in the vicinity of Zone B (Figure 2-12). Soil samples were collected from 10, 20, 30, and 40 feet bgs in each boring and submitted for SVOCs, priority pollutant metals, herbicides, and dioxins analysis. The results of the Phase I analyses are summarized as follows:

- no herbicides were detected in either boring;
- low levels of di-n-butyl phthalate, bis(2-ethylhexyl) phthalate, and di-n-octyl phthalate were detected in samples submitted for SVOC analyses;
- all priority pollutant metals were at or below site background levels; and
- dioxins were detected in soil samples from both borings.

The results of soil sampling performed during the Phase I investigation indicated the presence of dioxins in soil samples from borings B-05 and B-06 (Figure 2-12). Dioxins are known to occur as contaminants in herbicide wastes. Historical records indicate that Zone B contains approximately 5,000 drums of 2,4-D tar and MCPA-bleed derived from the herbicide manufacturing process. Therefore, a comparison between herbicide and dioxin concentrations in background and Zone B soil samples was conducted to assess whether a release of these compounds from the drummed wastes in Zone B had occurred. The results of this work are summarized below.

3.11.3.1 HERBICIDE AND DIOXIN ANALYSES

Herbicide concentrations were below detection limits for all background and Zone B soil samples. Therefore, a statistical comparison between background and Zone B soil was unnecessary for herbicides. Dioxins were detected in all background and Zone B samples (Table 3.30 and Table 3.31). A statistical evaluation was required to assess whether dioxin concentrations in Zone B soil were statistically greater than calculated site background concentrations.

3.11.3.2 STATISTICAL ANALYSIS

A statistical evaluation of background versus Zone B soil was performed using two different sets of tests. The first set consisted of tests specified in the State of Washington Department of Ecology (Ecology), Toxics Cleanup Program, Statistical Guidance for Ecology Site Managers (Ecology 1992, 1993). The Ecology evaluation consisted of three tests comparing dioxin concentrations in background with Zone B concentrations. In accordance with the Ecology guidance, Zone B soil was concluded to exceed calculated site background values if at least one of the following observations was found to be true:

- the one-sided 95 percent upper confidence limit (UCL) for the mean dioxin concentration in Zone B soil exceeded the calculated site background value;
- more than 20 percent of Zone B dioxin concentrations exceeded the calculated site background value; or
- the Zone B concentration exceeded twice the calculated site background value for a given dioxin.

The results of the Ecology tests indicate that 21 of the 24 dioxin congeners and congener totals detected in Zone B soil exceeded their respective calculated site background concentrations. It should be noted that although 20 background samples were submitted for analysis of dioxin concentrations, low surrogate recoveries for some of the congeners resulted in availability of only 16 values for use in calculating background concentrations.

A second statistical evaluation was performed for comparison with the Ecology test results. The second evaluation consisted of a set of statistical tests developed by Hardin and Gilbert (1993) for the US Department of Energy. The results of this evaluation indicated that Zone B soil exceeded calculated site background concentrations for only 4 of the 24 dioxin congeners. Boring B-13 exceeded the calculated site background concentrations for only one dioxin congener (2,3,7,8-TCDF) in the sample from 20 feet bgs using the Hardin and Gilbert methodology. Boring B-14 exceeded background for three congeners in the sample from 20 feet bgs, and MW-26S exceeded background for four congeners in the sample from 5 feet bgs. No samples collected from boring B-15 exceeded calculated site background dioxin concentrations using the Hardin and Gilbert methodology.

A more complete discussion of the statistical analyses performed is provided in Appendix K of this report. Ecology's response regarding the effect of calculating site background values with less than 20 samples has been included as part of Appendix K.

3.11.3.3 COMPARISON WITH MTCA METHOD B VALUES

As a means of evaluating the potential impact of dioxins in soil surrounding Zone B on human health and the environment, a comparison was made between the concentrations of the dioxin congeners that exceed calculated site background values using the Ecology methodology and MTCA Method B formula values calculated for the individual dioxin congeners (Table 3.32). MTCA Method B values were only calculated for individual dioxin congeners (e.g., 1,2,3,4,6,7,8-HpCDF; 2,3,7,8-TCDF; etc.) and not for total congeners [e.g., OCDF (total), TCDFs (total), etc.].

Based on the methodology presented in the current US Environmental Protection Agency (USEPA) guidance (USEPA, 1989), it is inappropriate to calculate risk-based (MTCA Method B) cleanup values for total congeners. According to this guidance, although nearly all of the 210 CDDs/CDFs occur at very low levels throughout the environment, only the 2,3,7,8-substituted congeners are selectively absorbed and/or retained in higher animals (e.g., fish, humans, and other mammals). As a result, only 2,3,7,8-substituted congeners are assigned toxicity equivalence factors (TEFs) while non-2,3,7,8-substituted congeners are assigned TEFs of zero (USEPA 1989).

The results of the comparison between dioxin concentrations in Zone B soil and MTCA Method B formula values reveal that none of the dioxin congeners exceed their respective MTCA Method B formula values.

3.11.4 GROUNDWATER CHEMISTRY, ZONE B

Three wells (EE-4, EE-5, and MW-26S) have been designated as Zone B Monitoring Wells for the purpose of providing an assessment of groundwater conditions in the vicinity of Zone B. Offsite well MW-25S was used to provide upgradient data.

3.11.4.1 VOLATILE ORGANIC COMPOUNDS

Table 3.33 contains a summary of VOCs detected in wells EE-4, EE-5, MW-25S, MW-26S, MW-28S, and NW-5. Wells EE-4, EE-5, and MW-26S were designated as Zone B Monitoring Wells and were used for assessing of groundwater conditions in the vicinity of Zone B. Data from wells MW-25S, MW-28S, and NW-5 were evaluated to assess the distributions of contaminants in background wells upgradient from Zone B.

A total of 17 VOCs were detected in Zone B Wells during Phase II sampling. Ten were also detected in upgradient background wells; three (cis-1,2-DCE, 1,1-DCE, and 1,1-DCA) are biotransformation products of compounds detected in upgradient wells during the same sampling event; and two of the remaining three (2-hexanone and 4-methyl-2-pentanone) were detected during only one sampling event. No VOCs were detected above their MTCA Method B formula values downgradient from Zone B. However, 1,1-DCE was detected above its Method B formula value in upgradient well MW-25S in May 1995 (Figure 3-55 and Table 3.34).

The majority of VOC detections in Zone B Wells occurred during the first two sampling events. Fourteen were only detected during the 2nd Quarter 1995 sampling event, while three were detected only during the 2nd and 3rd Quarters of 1995. No VOCs were detected in any Zone B Wells during the 4th Quarter 1995 sampling event. The following section provides a discussion of each of the 20 VOCs detected in Zone B Wells, the frequency of detection and range of concentrations observed, and comparisons between the distributions of VOCs in Zone B and background wells.

Three chlorinated ethenes [PCE, TCE, and cis-1,2-DCE (a biotransformation product of PCE/TCE dehalogenation; Figure 3-25)] were detected in Zone B Wells during June 1995. PCE, TCE and 1,1-DCE were also detected in background wells during June 1995. The mechanism for transport of PCE, TCE, and cis-1,2-DCE into groundwater beneath Zone B is unclear; however, it is important to note that these compounds were only detected during the first round of Phase II groundwater monitoring (June 1995) and have not been detected in any subsequent samples from Zone B Wells. A description of their distributions in groundwater surrounding Zone B follows:

- PCE was detected in Zone B Wells EE-4 (0.035 µg/L) and MW-26S (0.039 µg/L) during one sampling event (June 1995). PCE was also detected at 0.026 µg/L in

upgradient well NW-5 during June 1995. The PCE concentrations reported in these three wells were each less than 0.1 µg/L and were flagged as estimated concentrations by the data validation team. The similarity between the reported concentrations in Zone B Wells EE-4 and MW-26S and upgradient well NW-5 indicate that the source of PCE is not associated with Zone B.

- TCE was detected at 0.13 µg/L in well MW-26S during June 1995, but was also detected at 0.19 µg/L and 0.043 µg/L in upgradient background wells MW-25S and MW-28S, respectively, during this same event. The occurrence of TCE at higher concentrations in upgradient background wells MW-25S and MW-28S, indicate that its presence in groundwater is not associated with Zone B.
- Cis-1,2-DCE (a biotransformation product of PCE/TCE degradation) was detected in Zone B Well MW-26S during June 1995, but was not detected in any other samples from Zone B Wells during any subsequent sampling events. Likewise, 1,1-DCE (another biotransformation product of PCE/TCE degradation) was not detected in any Zone B Wells, but was detected in upgradient well MW-25S during June 1995. It is not possible to make conclusions regarding the source of this compound in groundwater based on a single detection. However, the single detection of cis-1,2-DCE in MW-26S along with the occurrence of its parent products, PCE and TCE, in upgradient background wells MW-25S and MW-28S during this same event, indicate that its presence in groundwater is not associated with Zone B.

Three chlorinated ethanes (1,1,2-TCA, 1,2-DCA, and 1,1-DCA) were detected in Zone B wells during Phase II sampling (Table 3.33). The distribution of chlorinated ethanes in groundwater surrounding Zone B is described as follows:

- 1,1,2-TCA was detected in only two samples: the June 1995 and September 1995 samples from Zone B Well MW-26S. The detected concentrations were both below the laboratory practical quantification limits and were flagged as estimated values by the data validation team. Because 1,1,2-TCA was only detected twice and at concentrations below the quantification limits, it is inappropriate to make conclusions regarding the source of the compound.
- The compound 1,2-DCA was detected at similar concentrations (between 0.31 and 0.35 µg/L) in all Zone B Wells as well as upgradient well MW-25S and was detected in 32 of the 39 wells sampled across the site during June 1995, including upgradient background wells MW-28S and NW-5. The compound 1,2-DCA was not detected in any Zone B Wells during any subsequent sampling events indicating that its presence in groundwater is not associated with Zone B.
- 1,1-DCA was detected in only one sample: the June 1995 sample from Zone B Well MW-26S. The detected concentration was below the laboratory practical quantification limits and was flagged as an estimated value by the data validation team. The source of 1,1-DCA in groundwater is unknown.

- Chloroethane, a biotransformation product of 1,1,2-TCA, 1,2-DCA, and 1,1-DCA (Table 3.33) was not detected in any samples from Zone B Wells, but was detected in upgradient wells MW-25S, MW-28S, and NW-5 (0.49, 0.87, and 0.69 $\mu\text{g/L}$, respectively) during the 2nd quarter 1995 sampling event and upgradient well MW-28S (0.17 $\mu\text{g/L}$) during the 4th quarter 1995 sampling event. For these reasons the presence of chloroethane does not appear to be associated with Zone B.

Four chlorinated methanes [trichlorofluoromethane, chloroform (trichloromethane), methylene chloride (dichloromethane), and chloromethane] were detected in groundwater samples from Zone B Wells. Their distributions in groundwater surrounding Zone B are as follows:

- Trichlorofluoromethane was detected at the same concentration (0.087 $\mu\text{g/L}$) in Zone B Well MW-26S and upgradient background well MW-25S during the September 1995 sampling event. Trichlorofluoromethane was not observed in any Zone B Wells or upgradient wells during any subsequent sampling event; however, its presence in groundwater at the same concentrations in both upgradient and downgradient wells during September 1995 indicates that it is not associated with Zone B.
- Chloroform not detected in any Zone B Wells during any sampling event, but was detected in one sample from upgradient well MW-25S (0.022 $\mu\text{g/L}$ during June 1995). For this reason, the presence of chloroform does not appear to be associated with Zone B.
- Methylene chloride was detected in Zone B wells EE-4 and EE-5 (1.2 and 1.3 $\mu\text{g/L}$, respectively) during the September 1995 sampling event. Both samples contained comparable levels of methylene chloride in the associated method blank and were flagged as estimated concentrations by the data validation team. Methylene chloride was also detected in upgradient wells MW-25S and MW-28S during the June 1995 sampling event, but was not detected in any other samples from Zone B Wells. These data suggest that the presence of methylene chloride is either the result of a potential upgradient source or was introduced as an analytical contaminant at the laboratory.
- Chloromethane was detected in all Zone B wells, as well as upgradient background wells MW-25S, MW-28S, and NW-5 during June 1995, with the highest concentrations observed in upgradient well MW-25S. Chloromethane was not observed in any Zone B Wells during subsequent sampling events indicating that its presence in groundwater is not associated with Zone B.

Four ketones (acetone, 2-butanone, 2-hexanone, and 4-methyl-2-pentanone) were detected in Zone B Wells with the majority of detections occurring during the June 1995 sampling event. Ketone distributions in Zone B groundwater can be described as follows:

- Acetone was detected in Zone B Wells during two sampling events (June 1995 and July 1996). Each of the detections was well below the MTCA Method B formula value for acetone. Acetone was detected in all three Zone B Wells during June 1995, with concentrations ranging between 2.5 and 4.4 µg/L. However, acetone was also detected at similar concentrations (0.75, 0.78, and 4 µg/L) in upgradient background wells MW-25S, MW-28S, and NW-5, respectively, during this same event, indicating that its presence in groundwater is not associated with Zone B. Acetone was only detected in one other sample from Zone B Wells (7 µg/L in the July 1996 sample from MW-26S).
- 2-butanone was detected at concentrations ranging between 0.26 and 0.32 µg/L in Zone B Wells EE-4 and EE-5, and 0.21 µg/L in upgradient background wells MW-25S and MW-28S during June 1995. The compound 2-butanone was not detected in any of these wells (or any other Zone B Wells) during any subsequent sampling event, indicating that its presence in groundwater is not associated with Zone B.
- 2-hexanone was only detected in two samples from the Zone B Wells (EE-5 and MW-26S). Both detections occurred during the June 1995 sampling event. The compound 2-hexanone was not detected in any Zone B Wells during subsequent sampling events indicating that its presence in groundwater is not associated with Zone B.
- The compound 4-methyl-2-pentanone was only detected in one Zone B sample: the July 1996 sample from well MW-26S. The compound 4-methyl-2-pentanone was not detected in any Zone B Wells during subsequent sampling events indicating that its presence in groundwater is not associated with Zone B.

Five additional VOCs (1,2-dichloropropane, toluene, benzene, chlorobenzene, and carbon disulfide) were detected in groundwater samples from the Zone B Wells (Table 3.33) or upgradient well MW-25S. The distributions of these compounds in groundwater surrounding Zone B follows:

- The compound 1,2-dichloropropane was detected in two samples from Zone B Wells (EE-4 and MW-26S). Both detections occurred during the June 1995 sampling event. The compound 1,2-dichloropropane was not detected in any Zone B Wells during subsequent sampling events, indicating that its presence in groundwater is not associated with Zone B.
- Toluene was detected in all Zone B Wells, as well as upgradient background wells MW-25S, MW-28S, and NW-5, during the 2nd quarter 1995. The highest concentrations were observed in the upgradient background wells, indicating that its presence in groundwater is not associated with Zone B. Toluene was not observed in any Zone B Wells or upgradient wells during any subsequent sampling events.

- Benzene was not detected in any samples from Zone B Wells, but was detected in upgradient wells MW-25S and MW-28S (0.04 and 0.18 $\mu\text{g/L}$, respectively) during the 2nd quarter 1995 sampling event. Likewise, chlorobenzene was not detected in any samples from Zone B Wells, but was detected in upgradient wells MW-25S and MW-28S (0.23 and 0.059 $\mu\text{g/L}$, respectively) during the 2nd quarter 1995 sampling event, indicating that its presence in groundwater is not associated with Zone B.
- Carbon disulfide was not detected in any Zone B Wells during the 2nd quarter 1995, but was detected in upgradient wells MW-25S and MW-28S (0.028 and 0.035 $\mu\text{g/L}$, respectively). Carbon disulfide was detected in Zone B Wells EE-4 and EE-5 (0.025 and 0.021 $\mu\text{g/L}$, respectively) during the 1st quarter 1996, but was also detected in upgradient well MW-25S during this same sampling event. Its occurrence in upgradient background wells indicates that the presence of carbon disulfide in groundwater is not associated with Zone B.

In summary, a total of 16 VOCs were detected in Zone B Wells with 14 of the 16 detected only during one sampling event (June 1995); 10 of the 16 VOCs detected in Zone B Wells were also detected in upgradient background wells during the same sampling event; and 3 are degradation products of VOCs detected in upgradient wells. Three compounds (1,1-TCA, 2-hexanone, and 4-methyl-2-pentanone) were not detected in upgradient wells. However, 2-hexanone and 4-methyl-2-pentanone were only detected during the June 1995 sampling event. Together, these data indicate that Zone B is not acting as a source of VOCs in groundwater.

3.11.4.2 SEMI-VOLATILE ORGANIC COMPOUNDS

Three Zone B Wells (EE-4, EE-5, and MW-26S) and one upgradient background well (MW-25S) were sampled during the Phase II investigation to assess Zone B as a source of SVOCs in groundwater. A total of eight SVOCs (phenol, benzyl alcohol, dimethyl phthalate, 2,6-dinitrotoluene, diethyl phthalate, di-n-butyl phthalate, butyl benzyl phthalate, and di-n-octyl phthalate) were detected in Zone B Wells. Three of the eight SVOCs detected in Zone B Wells (phenol, benzyl alcohol, and diethyl phthalate) were detected in only one sample. Each of these compounds was detected at concentrations below the laboratory's practical quantification limits and the concentrations were flagged as estimated quantities (Table 3.35).

Butyl benzyl phthalate was detected in three samples: the June 1995 and September 1995 samples from EE-4, and the June 1995 sample from MW-26S. Each of these detections was below the laboratory's practical quantification limit. Di-n-octyl phthalate and 2,6-

dinitrotoluene were each detected once: the June 1995 and September 1995 samples from MW-26S, respectively.

Three SVOCs (hexachloroethane, naphthalene, and 2-methyl naphthalene) were detected in background well MW-25S, but were not detected in any Zone B Well. Dimethyl phthalate and di-n-butyl phthalate were detected in both background and Zone B Wells. Dimethyl phthalate was detected in background well MW-25S and Zone B Well MW-26S in the June 1995 sample. These were the only samples from Zone B that contained dimethyl phthalate. Di-n-butyl phthalate was detected in four samples: the September 1995 samples from wells MW-25S and MW-26S, and the December 1995 samples from wells EE-4 and EE-5. Di-n-butyl phthalate was also detected in the method blanks for each of these four samples.

The concentrations of each of the SVOCs detected in Zone B Wells, as well as those detected in background well MW-25S, were well below the MTCA Method B formula values for the respective compounds. These results indicate that Zone B is not acting as a significant source of SVOCs in groundwater.

3.12 ZONE A/NORTH-SOUTH BURN TRENCH/BALEFILL

3.12.1 GEOPHYSICAL INVESTIGATION, ZONE A/NORTH-SOUTH BURN TRENCH

3.12.1.1 GROUND PENETRATING RADAR

The Phase II GPR results indicate the presence of a strong reflector at a depth of approximately two feet bgs across most of the survey areas at Zone A. This reflector is thought to represent the polyethylene sheeting placed over the zone during closure. Due to its strong reflective nature, there is very little resolution of subsurface features below the depth of the reflector.

GPR data from Zone A indicate that variations in depth to the polyethylene liner (generally less than a foot) occur across the survey area. It is not clear whether they are the result of subsidence within the areas containing drummed waste, or placement of the liner over an uneven surface during closure of the zones.

As at Zone B, the presence of the plastic sheeting prevented assessment of the thickness of the soil cover over the zone. Likewise, evidence of subsidence of the soil cover overlying the

zone could not be assessed. The GPR survey did, however, confirm the presence of the polyethylene cover which would inhibit infiltration of precipitation into the zone. Additional discussion of the GPR survey results are provided in Appendix E.

3.12.1.2 EM-31 AND GROUND MAGNETICS SURVEY

The Phase I and II ground magnetics and EM-31 data sets were merged to provide a more complete picture of Zone A and the North-South Burn Trench. The outline of buried drums in Zone A is expressed by both the in-phase EM-31 data and ground magnetics data. The total magnetic field and vertical magnetic gradient data indicate two distinct zones of elevated signal intensity, corresponding to the area of stacked drums within the surveyed boundaries of Zone A and the area of randomly disposed drums adjacent to the surveyed boundaries of Zone A (Figure 3-56 through Figure 3-59).

The EM-31 in-phase data (Figures 3-60 and 3-61) provide the best definition of the area of stacked drums in Zone A. These data indicate that the area of stacked drums extends approximately 45 feet west and approximately 30 feet north of the surveyed western boundary and is more irregular in shape than reported in the closure survey. The data also suggest two distinct areas of stacked drums separated by an area of reduced in-phase signal. Examination of air photos (ASCS 53021173-139B and 53021173-78B) taken during drum stacking operations reveals that this area of reduced signal corresponds to the former access road used for off-loading drums in Zone A.

In addition, an intermediate-strength anomaly occurs in the in-phase EM-31 data west of the area of stacked drums. The location of this anomaly agrees well with the reported location of the randomly-placed drums and refuse deposited along the western edge of Zone A, as shown on aerial photograph FBR 1-5 taken in late October of 1973 just prior to initiation of drum stacking.

The outline of the North-South Burn Trench is best expressed in the EM-31 apparent and in-phase conductivity data (Figures 3-60 through 3-63). These data indicate that the highest concentration of metallic wastes are located in the inner portion of the trench and that this may represent the core area of the burn pit. The apparent and in-phase conductivity data also suggest that the North-South Burn Trench was located primarily to the east of the present Municipal Landfill access road.

The Balefill areas are characterized by elevated, chaotic signals in both magnetic and EM-31 data. However, distinctions between the Balefill areas and adjoining areas of inert waste fill are not clearly defined, potentially due to the proportion of metal present in the inert waste. A linear area of reduced signal intensity (fill dirt) is clearly visible along line 400 north between the two areas of baled waste. An additional anomaly corresponding to the location of a buried cement mixer drum (Larry Dietrich, personal communication, 1992), is evident on the EM-31 in-phase map (Figure 3-60) at the intersection of lines 460 north and 80 east.

3.12.1.3 EM-34 SURVEY

The primary objective of the EM-34 reconnaissance survey was to assess the area below Zone A for evidence of an anomalous conductivity response at depth that might be indicative of a potential release. All EM-34 HDM data indicate that conductivities return to background levels fairly rapidly to the west of the burn trench. None of the geophysical data gathered indicate the presence of a shallow inorganic contaminant plume emanating from Zone A. However, measurements representative of soil conductivities at depth could not be collected directly under Zone A due to the strong masking effect exhibited by the metallic drums.

As with the EM-31 and magnetics data, the EM-34 data suggest two distinct areas of drum disposal associated with Zone A (Figure 3-64 and Figure 3-65). The difference between the orderly stacked drums within Zone A and the randomly disposed drums to the west of Zone A is expressed by the contrast in the EM-34 apparent conductivity signature emanating from the two zones. The area of randomly disposed drums to the west is observed as a positive conductivity anomaly, while the area containing the closely stacked drums to the east is expressed as a negative anomaly.

3.12.2 DRUMMED WASTE CHARACTERIZATION STUDY, ZONE A

As discussed in Section 2.12.2 above, a Drummed Waste Characterization Study was completed at Zone A. The results of the various studies are included below.

3.12.2.1 GEOPHYSICS

Results of the GPR and EM surveys were discussed in Section 3.12.1.

3.12.2.2 SOIL-GAS SURVEY

Results of the Drummed Waste Characterization soil-gas survey at Zone A indicate elevated concentrations of carbon dioxide and depressed concentrations of oxygen in the vadose zone in the vicinity of Zone A (Table 3.36). Methane was detected in significant concentrations in only two locations, PH-36 and PH-38, which are the two locations nearest the drum disposal area in Zone A (Figure 2-14). Acid gas was not detected in any sample analyzed during this survey. The soil-gas probe located northwest of Zone A (PH-36), exhibited the lowest concentrations of oxygen (1.9 percent), and the highest concentrations of carbon dioxide (160,000 mg/L) and methane (3,654 mg/L).

The presence of methane and carbon dioxide above ambient atmospheric concentrations, accompanied by the reduced oxygen concentrations observed in soil-gas probes, indicates that biodegradation is occurring in the vicinity of Zone A. The soil-gas analysis provides no evidence of corrosive gas which might limit the life expectancy of the drums within Zone A.

3.12.2.3 CORROSIVITY SURVEY

Samples collected from the vapor extraction wells installed near Zone A were submitted to an offsite laboratory to measure resistivity in both as-received and water-saturated soil. These data were used to generate a corrosivity index as described in Section 2.11.2.3. The average resistivity for as-received soil was 38,700 ohm-cm (Table 3.37). The resulting corrosivity index ranged from 11 to 23, with an average of 17.7 (Table 3.38). Assuming a steel drum wall thickness of 0.104 cm (0.041 inches), this indicates that the drums may have been penetrated by pitting three to five years before the survey was completed in 1995 (i.e., between 1990 and 1992). The average resistivity for water-saturated soil was about 7,100 ohm-cm. The corrosion index for water-saturated samples ranged from 14-24 ohm-cm, with an average of 20.3 ohm-cm, indicating that penetration of the drums may have occurred five to seven years before the survey was completed in 1995 (i.e., between 1988 and 1990).

Since the distilled water used to saturate the samples should have an infinitely high resistivity, addition of the water to the soil should increase or leave unchanged the resistivity of the soil. However, in all cases, both at Zone A and Zone B, the resistivity of the soil decreased significantly with the addition of water. This indicates the presence of significant quantities of dissolved salts in the soil. The presence of dissolved salts would result in significantly greater corrosion during periods of heavy rain or other times of infiltration of water.

A comparison between laboratory and *in-situ* resistivity indicates that laboratory resistivity for Zone A soil is approximately 1,000 percent higher than the *in-situ* results. This is an atypically high result for comparisons between laboratory and *in-situ* resistivity measurements. The samples submitted for laboratory resistivity measurements were collected from the vapor extraction (SVE) wells as they were installed, approximately 100 feet from where the *in-situ* testing was completed. The large difference between the *in-situ* and laboratory resistivity measurements indicates a difference in soil characteristics between the soil surrounding the SVE wells and the soil surrounding the drums. The *in-situ* testing results are considered more representative of soil surrounding the drums. In general, soil with resistivity below 2,000 ohm-cm is considered moderately corrosive, while soil with resistivity above 10,000 ohm-cm is considered significantly less corrosive. *In-situ* soil resistivity around Zone A ranged from 843 to 13,884 ohm-cm, with an average of 3,461 ohm-cm, indicating that the soil in the vicinity of Zone A is moderately corrosive.

An evaluation of potential internal corrosion rates for the drums in Zone A was conducted by utilizing corrosion rates in the "Chem-Cor" and "Cor-Sur" database to approximate drum corrosion rates for the different materials believed to be present in Zone A drums, based on the site history completed in Phase I. This comparison indicates typical drum corrosion rates of about 0.5 mils (0.0005 inches) per year. However, wastes such as pesticides and acids, which were reported to be present in Zone A, can have corrosion rates in excess of 50 mils (0.05 inches) per year. This higher rate would result in penetration of drums in less than one year. Additional information regarding the corrosivity survey can be found in Appendix F.

3.12.2.4 SELF POTENTIAL SURVEY

No SP anomalies greater than 50 mV were observed over the drum burial zone at Zone A. The highest SP readings observed in the Zone A survey were outside the Zone A boundary at the northeastern portion of the survey area. These elevated readings have been interpreted as stray currents from decomposition of metallic wastes in the balefill area.

As discussed in Section 2.11.2.4, a single drum corroding at a consistent rate over a period of twenty-years would generate a SP anomaly of approximately 260 mV. Based on this assumption, an anomaly of 50 mV would represent a single drum which is approximately 10 percent corroded. The largest anomaly not attributable to stray currents was approximately 20 mV. If the 20-mV anomaly is entirely attributed to a constant rate corrosion of a single drum, which has been occurring at that same rate since the drums were placed in the zone, then that drum would be approximately five percent corroded.

The SP results are inconclusive. The results could be interpreted as an indication that little corrosion has occurred in the soil underlying Zone A and that the drums are not significantly corroded. However, other data collected during this study, including the soil-gas and corrosivity surveys, support an alternative interpretation: that low corrosion rates exist today, with more aggressive corrosion rates having previously existed in the past. In addition, the drums may be acting in an anodic/cathodic relationship with each other, so that the resultant potential fields would not be detectable by surface SP methods. Additional information regarding the SP Survey can be found in Appendix G.

3.12.3 SOIL CHEMISTRY

Soil samples were collected from monitoring well boreholes MW-12I, MW-13S, and MW-14S at depths of 64.5, 60, and 45 feet bgs, respectively, during the Phase I field investigation and analyzed for VOCs, SVOCs, pesticide/PCBs and priority pollutant metals. The results of these analyses are summarized below.

- Pesticide/PCB analyses revealed the presence of 8.9 µg/kg of the pesticide 4,4'-DDT in the sample collected from 64.5 feet bgs in boring MW-12I. No other pesticides or PCBs were detected in the soil samples collected from Zone A.

- Two SVOCs (di-n-butyl-phthalate and di-n-octyl-phthalate) were detected in the soil samples from Zone A. However, di-n-butyl-phthalate was also detected in the method blank and as a result, these data are not considered representative of site conditions. Di-n-octyl-phthalate was detected below the practical quantitation limits in the sample from 64.5 feet bgs in MW-12I and was qualified as an estimated concentration by the analytical laboratory.
- Three VOCs (acetone, methylene chloride, and toluene) were detected in soil samples from MW-13S, and MW-14S. Each of these VOCs was also detected in the associated method blank, and as a result, these data are not considered representative of soil in the vicinity of MW-13S or MW-14S.
- Two VOCs (acetone and methylene chloride) were detected in the soil sample from 64.5 feet bgs in borehole MW-12I. Acetone was detected at 2,200 µg/kg. Methylene chloride was detected at 220 µg/kg. This result was below the practical quantitation limits and was qualified as an estimated concentration by the analytical laboratory.
- All priority pollutant metals were at or below site background levels.

A more detailed discussion of soil samples collected from MW-12I, MW-13S, and MW-14S during the Phase I field investigation is provided in the Phase I RI Report (Burlington Environmental Inc., 1994). No soil samples from Zone A, the North-South Burn Trench, or the Balefill Areas were collected for laboratory chemical analysis during the Phase II field investigation.

3.12.4 SOIL-GAS

The soil-gas investigation at Zone A consisted of two distinct efforts: an assessment of oxygen, methane, and carbon dioxide levels in soil surrounding the drummed waste in Zone A, performed as part of the Drummed Waste Characterization Study (Philip 1996); and an assessment of VOCs in soil-gas surrounding Zone A. The bulk of the assessment of VOCs in soil-gas surrounding Zone A was performed as part of the Phase I field investigation, with supplemental soil-gas probeholes installed as part of the SVE Treatability Study at Zone A (Philip 1995). The results of the Drummed Waste Characterization Study Soil-Gas Survey are discussed in Section 3.12.2.2.

Twenty-nine soil-gas samples were collected from twenty-seven probeholes during the Phase I field investigation to evaluate the nature and extent of VOCs in the vadose zone in the vicinity of Zone A, Zones C and D, and the Municipal Landfill. Soil-gas samples from each borehole were analyzed for VOC concentrations in the field using a gas chromatograph (GC) analyzer (Table 3.39).

Ten confirmatory samples were submitted for VOC analysis in an offsite laboratory (Table 3.40). The results of these analyses are summarized briefly below.

- A total of 13 VOCs have been detected in soil-gas samples at the site.
- Eight VOCs (1,1-DCE, trans-1,2-DCE, 1,1-DCA, chloroform, 1,1,1-TCA, TCE, toluene, and PCE) were detected in soil-gas samples screened in the field. Each of these compounds was also detected in samples submitted for laboratory analysis.
- Vinyl chloride, methylene chloride, and acetone were not available for analysis in the field, but were detected in samples submitted for laboratory analysis.
- Each of the 13 VOCs detected in soil-gas during Phase I has also been detected in groundwater.

Complete results are provided in the Phase I RI Report (Burlington Environmental, 1994).

Six additional probeholes were installed in the vicinity of Zone A during the Phase II field investigation as part of the Drummed Waste Characterization Study (Philip, 1996a). Samples from these boreholes were analyzed in the field for select VOCs. Four clusters of landfill gas probes have also been installed in the area surrounding the Municipal Landfill. The results of VOC analyses from soil-gas probeholes and landfill gas probes have been combined in the following discussion. The results of VOC analyses from Phase II soil-gas probeholes are provided in Table 3.41 and Table 3.42. Figures 3-66, 3-67, and 3-68 provide chemical concentration contour maps showing the distribution of 1,1-DCE, TCE, and PCE in soil-gas and landfill-gas. These maps were prepared using a combination of Phase I and Phase II soil-gas data and landfill-gas data from the June 5, 1995 landfill-gas sampling event. These maps were prepared primarily using Phase I data. The Phase II data were treated as supplemental to the Phase I soil-gas survey data.

Although the Phase II soil-gas samples were collected more than two years after the Phase I samples, the data appear to agree relatively well. For example, Phase II borehole PH-36 was installed approximately 70 feet north and 32 feet east of Phase I borehole PH-04. Soil-gas from PH-04 contained 345 µg/L of 1,1-DCE, 162 µg/L of TCE, and 46 µg/L PCE in October 1992. Similarly, soil-gas samples from PH-36 contained 450 µg/L of 1,1-DCE, 169 µg/L of TCE, and 60 µg/L of PCE in May 1996.

As can be seen from Figures 3-67 and 3-68, TCE and PCE are present in soil-gas across a large portion of the site. Their presence appears to be primarily associated with Zone A, the North-South Burn Trench, and the former Municipal Landfill. The highest concentrations of both

compounds occur in the southwest portion of the site adjacent Zone A and the North-South Burn Trench.

The chemical concentration contour map for 1,1-DCE (Figure 3-66) indicates that the highest concentrations of 1,1-DCE in soil-gas are located in the area surrounding Zone A and the North-South Burn Trench. A relatively large negative anomaly occurs along the eastern portion of this region which corresponds to the location of a gully approximately 15 feet deep with lateral dimensions approximately equivalent to the size of the negative soil-gas anomaly. It is unclear what relationship the existence of the gully has, if any, to the occurrence of the soil-gas anomaly.

The soil-gas concentration map for 1,1-DCE presented in the Phase I report indicated that 1,1-DCE was present in landfill gas in the vicinity of LFG-01 and LFG-02. However, although 1,1-DCE was detected at 8 µg/L in landfill gas probe LFG-01D during the Phase I field investigation, it was not detected in any other landfill gas samples collected during either Phase I or Phase II.

3.12.5 TIME-SERIES ANALYSIS

As discussed in Section 2.12.5 above, a time-series analysis study was conducted in Zone A Wells EE-2 and EE-3 on May 31, 1995, to assess the potential for these two wells as conduits for downward migration of contaminants to groundwater from Zone A. The results of this study are discussed below.

Concentrations of VOCs in EE-2 increased in the first three samples collected, followed by fluctuating concentrations over the remainder of the test. Conversely, VOCs in EE-3 generally decreased sharply over the first one or two samples then stabilized or exhibited a slight general decline over the remainder of the test. However, several chlorinated VOCs exhibited increasing concentrations in the sample collected at 160 minutes (15 well volumes), followed by slightly decreasing concentrations throughout the remainder of the test.

The SVOC concentrations in EE-3 generally decreased over the first three samples, followed by fluctuating concentrations over the remainder of the test. No SVOCs were detected in EE-2 during the time series analysis.

Chromium was the only metal detected in either well. Chromium concentrations in both wells showed a significant decrease from the first to the second sample, followed by fluctuating concentrations throughout the remainder of the test.

Data from the time-series analysis do not exhibit a consistent trend and are therefore inconclusive with respect to an assessment of well integrity. These observations agree with those of Gibs and Imbrigotta (1990), which conclude that continued purging of a well can cause contaminant concentrations to fluctuate to the point of unreproducability. Data from EE-3 indicate overpurging after removal of approximately 10 to 15 well volumes. Data from EE-2 also indicate signs of overpurging, although not to the degree evident in EE-3. In neither case do the data suggest a significant increase or decrease in contaminant concentrations with continued purging. Therefore, these data do not provide data relevant to an assessment of well integrity at EE-2 or EE-3. Analytical results from the time series analysis are provided in Appendix I.

3.12.6 GROUNDWATER CHEMISTRY

Ten wells (#1, #2, EE-2, EE-3, MW-10S, MW-11S, MW-12S, MW-12I, MW-12ID, and MW-13S) have been designated as Zone A Wells for the purpose of providing an assessment of groundwater conditions in the vicinity of Zone A. Three additional wells were used to assess groundwater upgradient from Zone A. Well MW-14S is located hydraulically upgradient from Zone A. Wells #3 and MW-18S provide monitoring points to assess groundwater quality between the Municipal Landfill and Zone A.

3.12.6.1 VOLATILE ORGANIC COMPOUNDS

The results of Phase I and II monitoring indicate that VOCs migrating from the material in Zone A are impacting groundwater. A total of 37 VOCs have been detected in groundwater samples collected from the Zone A Wells. The highest concentrations of VOCs were detected in well EE-3, which contained eighteen VOCs above Method B cleanup levels. The next highest concentrations of VOCs occurred hydraulically downgradient from Zone A in wells #2 and MW-12S. Well #2 contained ten VOC above MTCA Method B formula values. Well MW-12S contained eight VOC above MTCA Method B formula values. A summary of VOCs detected above MTCA Method B formula values in Zone A Wells is provided in Table 3.42. An

illustration of the distribution of VOCs detected above MTCA Method B formula values in Zone A Wells is provided in Figure 3-69.

As can be seen in Figure 3-69, PCE exceeded its Method B formula value in 11 Zone A Wells; TCE and 1,2-DCA exceeded Method B in 9; and vinyl chloride exceeded Method B in 8 Zone A Wells. The compound 1,1-DCE was detected in excess of its MTCA Method B formula values in all 13 Zone A Wells, including upgradient wells #3, MW-18S, and MW-14S.

Although VOCs have been detected in upgradient wells #3, MW-18S, and MW-14S, the results of the soil-gas survey indicate that soil-gas emanating from Zone A may be contributing to VOC concentrations in these wells. In any case, the results of Phase I and II monitoring indicate that VOCs from the material in Zone A are impacting groundwater.

3.12.6.2 SEMI-VOLATILE ORGANIC COMPOUNDS

A total of 22 SVOCs were detected in samples from Zone A Wells (Table 3.44). Of the 22 SVOCs detected, the highest concentrations generally occurred in wells EE-3, #2, or MW-12S, adjacent to or slightly downgradient from Zone A. Nine of the 22 SVOCs were only detected in wells EE-3, #2, or MW-12S. Two compounds were also detected in well MW-13S, to the west of Zone A, well MW-12I southwest of the zone, or well MW-10S at the downgradient property boundary.

Of the remaining eleven SVOCs detected at Zone A, ten were also detected in upgradient wells. The majority of these detections were at concentrations near or below the laboratory's practical quantification limits and were flagged as estimated concentrations. Two compounds [di-n-butyl-phthalate and bis(2-ethylhexyl)phthalate], were detected in the associated laboratory blanks for all samples with detections above the practical quantification limits. The remaining compound (2-chloro-phenol) was only detected in one sample: the May 1995 sample from well MW-13S. No SVOCs were detected in intermediate-depth well MW-12ID.

The concentrations of each of the SVOCs detected in the ten Zone A Wells, as well as those detected in the three upgradient wells, were all well below their respective MTCA Method B formula values. These results indicate that Zone A is not acting as a significant source of SVOCs to groundwater.

3.13 OFFSITE GROUNDWATER

Groundwater samples were collected from eleven cone penetrometer borings during the Phase II RI field effort to assess VOCs in groundwater downgradient from the site and provide reconnaissance data for placement of offsite monitoring wells. Seven VOCs (vinyl chloride, 1,1-DCE, trans-1,2-DCE, cis-1,2-DCE, TCE, PCE, and toluene) were detected in groundwater samples collected from the cone penetrometer borings. Of the seven VOCs detected in cone penetrometer samples, only PCE was detected in all eleven sampling locations. A table containing the complete results of VOCs analyses is provided in the attachment to the Technical Report in Volume II.

As can be seen in Figure 3-70, CP-6B contained the highest concentration of PCE, indicating that VOCs in groundwater were migrating offsite towards the southwest, hydraulically downgradient from the site. Based on these results and those of subsequent groundwater sampling events, offsite monitoring wells MW-29S through MW-42S were installed for the purpose of assessing impacts to offsite groundwater resulting from releases of contaminants from the site.

A total of 23 VOCs, 11 SVOCs, and 12 WAC 173-351-990 Appendix I Metals have been detected in groundwater samples collected from the Offsite Wells during the Phase II RI and Post-RI groundwater investigation. No herbicides were detected in any of the Offsite Wells. All SVOCs and WAC 173-351-990 Appendix I Metals were below MTCA Method B formula values in Offsite Wells with the exception of arsenic, beryllium, and lead.

3.13.1 VOLATILE ORGANIC COMPOUNDS

The results of Phase I and II monitoring indicate that groundwater containing VOCs in excess of MTCA Method B formula values are migrating from the site. A total of 23 VOCs were detected in groundwater samples collected from Offsite Wells MW-29S through MW-42S during Phase II RI and Post-RI sampling (Table 3.45). Seven VOCs (PCE, TCE, 1,1-DCE, vinyl chloride, 1,2-DCA, carbon tetrachloride, and benzene) were detected above MTCA Method B formula values (Table 3.45 and Figure 3-71).

The highest concentrations of VOCs in Offsite Wells were detected in well MW-29S, which contained five VOCs (PCE, TCE, 1,1-DCE, 1,2-DCA, and vinyl chloride) above their

respective MTCA Method B formula values (Figure 3-71 and Table 3.45). Each of these same VOCs also was also detected above Method B concentrations in wells MW-35S, MW-38S, and MW-41S, with concentrations generally decreasing with lateral distance hydraulically downgradient (south-southwest) from the site.

Chemical concentration contour maps were prepared for six selected indicator chemicals (PCE, TCE, 1,1-DCE, cis-1,2-DCE, vinyl chloride, and 1,2-DCA,) to illustrate the area of impacted groundwater extending offsite (Figures 3-72 through 3-119). Time versus concentration plots for the six indicator chemicals were also prepared to provide an evaluation of the variation in their concentrations over the course of Phase II RI and Post-RI sampling (Figures 3-120 through 3-125). Indicator chemicals were selected based on the chemical having exceeded its MTCA Method B formula value during at least two sampling events and having been detected in a sufficient number of wells to allow generation of a meaningful chemical contour map. The following section provides a discussion of each of the 23 VOCs detected in Offsite Wells, the frequency of detection, and the range of concentrations observed.

Six chlorinated ethenes (PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride) were detected in Offsite Wells during Phase II RI and Post-RI sampling (Table 3.44). Their distributions in offsite groundwater is as follows:

- PCE was detected in 55 of the 71 samples collected from Offsite Wells between June 1995 and February 1997 and was detected at least once in every Offsite Well with the exception of well MW-39S. The highest PCE concentrations in offsite groundwater were consistently observed in well MW-31S; MW-29S consistently contained the second highest concentrations (Figures 3-72 through 3-79). This trend is consistent with the PCE concentrations observed in wells MW-22S, MW-24S, and MW-11S located along the western boundary of the site, as well as the PCE concentrations measured in wells MW-10S and #1 along the southern boundary of the site.

The highest PCE concentrations detected at the site boundary were observed in well MW-24S, with the next highest concentrations occurring in well MW-10S. Well MW-24S is located approximately 500 ft. due west of the northern extent of Zone A and hydraulically down gradient from the Municipal Landfill. This indicates that the source of PCE in well MW-24S is associated with the Municipal Landfill. Likewise, well MW-10S is located hydraulically downgradient from Zone A. The PCE concentrations in MW-10S were consistently higher than those measured in surrounding wells MW-11S and #1, indicating that the source of PCE in well MW-10S is associated with Zone A. In addition, the PCE concentrations in MW-24S were consistently higher than those measured in well MW-31S, while PCE concentrations in MW-31S consistently exceeded those measured in well MW-29S. These results indicate that the PCE concentrations

observed in MW-31S may be related to releases from the Municipal Landfill, while the PCE in MW-29S appears to be related to Zone A.

Since their installation in July 1996, the PCE concentrations observed in wells MW-41S and MW-42S (the furthest downgradient wells) have consistently exceeded those measured in all Offsite Wells except MW-29S. Wells MW-30S, MW-31S, and MW-34S were removed from the groundwater monitoring program following the March 1996 sampling event, and as a result, no data for these wells are available for later sampling events.

- TCE was detected in 50 of the 71 samples collected from the Offsite Wells between the June 1995 and February 1997 and was detected at least once in every Offsite Well except well MW-39S. The highest TCE concentrations were observed in wells MW-29S, MW-35S, MW-38S, and MW-41S along a relatively narrow linear pathway extending south-southwest from Zone A (Figure 3-71 and Figures 3-80 through 3-87). Well MW-29S consistently contained the highest TCE concentrations with concentrations in wells MW-35S, MW-38S, and MW-41S, decreasing with distance from the site. Wells MW-29S, MW-35S, MW-38S, and MW-41S, located hydraulically downgradient from Zone A, were the only Offsite Wells containing TCE above MTCA Method B formula value (Figure 3-71). These four wells contain TCE concentrations more than an order of magnitude higher than those measured in other wells. These results indicate that the source of TCE in wells MW-29S, MW-35S, MW-38S, and MW-41S is associated with Zone A. The presence of TCE in wells MW-30S and MW-36S indicate that the Municipal Landfill is also contributing to the VOCs concentrations observed in these two Offsite Wells.
- Cis-1,2-DCE distributions in offsite groundwater are very similar to TCE distributions. Cis-1,2-DCE was detected in 56 of 71 samples collected from offsite groundwater and was detected at least once in every Offsite Well except well MW-39S. As with TCE, the highest cis-1,2-DCE concentrations were observed in wells MW-29S, MW-35S, MW-38S, and MW-41S along a relatively narrow linear pathway extending south-southwest from Zone A (Figures 3-88 through 3-95). Well MW-29S consistently exhibited the highest cis-1,2-DCE concentrations in offsite groundwater with the exception of December 1996 during which well MW-41S contained TCE concentrations in excess of well MW-29S (Figure 3-86). As with PCE, cis-1,2-DCE concentrations in well MW-41S frequently exceeded those measured in upgradient wells MW-35S and MW-38S, indicating that the VOC plumes emanating from the Zone A and the Municipal Landfill may be commingling.
- Trans-1,2-DCE, was only detected in 6 of the 71 samples collected from the offsite wells: the June 1995 samples from wells MW-29S and MW-31S, and the March 1996 samples from wells MW-29S, MW-31S, MW-35S, and MW-38S (Table 3.45). The cause for the variations in trans-1,2-DCE distributions in offsite groundwater is unknown; however, its occurrence in wells MW-29S, MW-35S, and MW-38S is consistent with a source in Zone A. Its occurrence in well MW-31S indicates that there may also be some contribution from the Municipal Landfill.

- The compound 1,1-DCE was detected in six Offsite Wells (MW-29S, MW-30S, MW-35S, MW-38S, MW-41S, and MW-42S) and exceeded the MTCA Method B formula values in four wells (MW-29S, MW-35S, MW-38S, and MW-41S) (Table 3.45). With the exception of a single detection (0.033 µg/L in well MW-30S during June 1995), each of these detections occurred along a relatively narrow linear pathway extending south-southwest from Zone A, indicating a source within Zone A (Figures 3-96 through 3-103).

The highest 1,1-DCE concentrations occurred most frequently in well MW-29S, the well nearest Zone A. However, 1,1-DCE concentrations in well MW-35S exceeded those measured in MW-29S during December 1995; both MW-35S and MW-38S exceeded MW-29S during March 1996; and wells MW-38S and MW-41S exceeded MW-29S in December 1996 (Figure 3-102 and Table 3.45). Although 1,1-DCE was detected in Landfill Wells during Phase II sampling, the data indicate that its presence in offsite groundwater is associated with a source in Zone A.

- Vinyl chloride distributions were similar to those observed for 1,1-DCE. Vinyl chloride was detected in four Offsite Wells (MW-29S, MW-35S, MW-38S, and MW-41S). Each of these detections occurred along a relatively narrow linear pathway extending south-southwest from the southwest corner of Zone A (Figures 3-104 through 3-111), indicating a source within Zone A. Each of these detections exceeded the MTCA Method B formula value (Table 3.45). As with 1,1-DCE, the highest concentrations of vinyl chloride generally occurred in well MW-29S, although well MW-35S was the only Offsite Well that contained vinyl chloride during December 1995, and well MW-41S contained slightly higher vinyl chloride concentrations during December 1996 (Table 3.45). Although vinyl chloride was also detected in Landfill Wells during Phase II sampling, the data indicate that its presence in offsite groundwater is associated with a source in Zone A.

Five chlorinated ethanes (1,1,2-TCA, 1,1,1-TCA, 1,2-DCA, 1,1-DCA, and chloroethane) were detected in offsite groundwater during Phase II RI and Post-RI sampling (Table 3.45). Their distribution in offsite groundwater can be described as follows:

- 1,1,2-TCA was detected in one sample each from two Offsite wells: the June 1995 sample from MW-29S and the October 1995 sample from well MW-35S. Both detections were below the MTCA Method B formula value. The compound 1,1,2-TCA was not detected in Landfill Wells, but was detected in Zone A Wells #2, EE-3, MW-10S, MW-11S, and MW-12S, indicating that its presence in offsite groundwater is associated with Zone A.
- 1,1,1-TCA was detected in seven Offsite Wells (MW-29S, MW-31S, MW-33S, MW-34S, MW-35S, MW-38S, and MW-40S) during Phase II RI and Post-RI sampling (Table 3.45). All detections were well below the MTCA Method B formula value of 7,200 µg/L for 1,1,1-TCA. The compound 1,1,1-TCA was detected in both Zone A and Landfill Wells during Phase II RI sampling, although the highest concentrations appear to be associated with Zone A. The maximum concentration was measured in the Landfill Wells was 1.5 µg/L in well #3 during June 1995. Zone A Well EE-3 contained 1,1,1-

TCA in excess of 700 µg/L during four sampling events. In addition, the concentrations measured in Offsite Wells MW-29S, MW-35S, MW-38S, and MW-40S, hydraulically downgradient from Zone A were approximately two orders of magnitude greater than those measured in the other Offsite Wells. These results indicate that the source of 1,1,1-TCA in offsite groundwater is related to Zone A, although the presence of 1,1,1-TCA in well MW-31S during June and October 1995 indicates that there may also be some lesser contribution from the Municipal Landfill.

- The compound 1,2-DCA was detected in offsite groundwater samples from six wells (MW-29S, MW-31S, MW-34S, MW-35S, MW-38S, and MW-41S). As with 1,1,1-TCA, the compound 1,2-DCA was detected in both Zone A and Landfill Wells during Phase II sampling. The maximum concentrations were detected in Zone A Well EE-3 (83 µg/L in July 1996). The concentrations of 1,2-DCA observed in well EE-3 exceeded the maximum concentrations measured in Landfill Wells (0.72 µg/L in well MW-16S during June 1995) by more than two orders of magnitude. In addition, the concentrations of 1,2-DCA in wells MW-29S, MW-35S, MW-38S, MW-41S, hydraulically downgradient from Zone A were consistently more than two orders of magnitude higher than those measured in wells MW-31S, and MW-34S, located more to the west (Figure 3-71 and Figures 3-112 through 3-119). These results indicate that the source of 1,2-DCA in offsite groundwater is related to Zone A, although the occurrence of 1,2-DCA in wells MW-31S and MW-34S during June and December 1995 indicates that there may also be some contribution from the Municipal Landfill.
- The compound 1,1-DCA has been detected at least once in every Offsite Well except MW-39S (Table 3.45) and was detected in wells MW-29S, MW-35S, MW-38S, MW-41S, and MW-42S during every sampling event (MW-35S was installed in September 1995 and removed from the sampling program in July 1996; MW-38S was installed in April 1996; MW-41S and MW-42S were installed in July 1996). All detections were below the MTCA Method B formula value. As with 1,1,1-TCA and 1,2-DCA, the compound 1,1-DCA was detected in both Zone A and Landfill Wells with maximum concentrations in Zone A Wells (770 µg/L in well EE-3) on the order of magnitudes higher than the maximum concentrations measured in Landfill Wells (7.8 in well #4). This is consistent with the 1,1-DCA concentrations observed in the Offsite Wells. The highest 1,1-DCA concentrations were consistently detected in wells MW-29S, MW-35S, MW-38S, MW-41S, and MW-42S, hydraulically downgradient from Zone A, with decreasing concentrations observed to the west in wells MW-30S, MW-31S, and MW-32S, hydraulically downgradient from the Municipal Landfill (Table 3.45). These results indicate that the primary source of 1,1-DCA is related to Zone A with lesser contributions from the Municipal Landfill.
- Chloroethane was detected in five Offsite Wells (MW-29S, MW-30S, MW-31S, MW-32S, and MW-35S) over the course of Phase II RI and Post-RI sampling. MW-29S was the only Offsite Well that contained chloroethane during more than one sampling event (Table 3.45). Each of the detections was below the laboratory practical quantification limits and was reported as an estimated concentration. The distribution of chloroethane in offsite groundwater indicates that its source is related to both Zone A and the Municipal Landfill.

Three chlorinated methanes [trichlorofluoromethane, chloroform (trichloromethane), and methylene chloride (dichloromethane)] were detected in samples collected from Offsite Wells.

Their distributions in offsite groundwater are as follows:

- Trichlorofluoromethane was detected in a total of five Offsite Wells (MW-29S, MW-31S, MW-32S, MW-35S, and MW-38S) during Phase II RI and Post RI sampling. Each of these detections occurred during the first four quarterly sampling events (June 1995 through March 1996) (Table 3.45). All were below the MTCA Method B formula value. Trichlorofluoromethane was not detected in any Offsite Wells during the subsequent four sampling events (July 1996 through February 1997). Trichlorofluoromethane was only detected once each in wells MW-31S and MW-32S (June 1995), but was detected during four sampling events (June 1995 through March 1996) in well MW-29S and three times (October 1995 through March 1996) in well MW-35S (MW-35S was not installed until after the June 1995 sampling event).

The source of trichlorofluoromethane in offsite groundwater is unclear. The highest concentrations in offsite groundwater consistently occurred in wells MW-29S or MW-38S hydraulically downgradient from Zone A. Trichlorofluoromethane was detected in both Zone A and Landfill Wells during the Phase II investigation, although the highest concentrations were detected in Zone A Wells #2 and EE-3. These results indicate that its occurrence in wells MW-29S and MW-32S during the first four sampling events is associated with both Zone A and the Municipal Landfill.

- Carbon tetrachloride was detected in three samples (MW-29S, MW-38S, and MW-41S) during December 1995, but was not detected in any other samples from Offsite Wells. Carbon tetrachloride was detected in Zone A Wells # 2 and EE-3 during Phase II sampling but was not detected in any Landfill Wells. As a result, its occurrence in Offsite Wells MW-29S, MW-38S, and MW-41S during December 1995 is interpreted as being associated with Zone A.
- Chloroform was detected in five Offsite Wells: MW-29S, MW-35S, MW-36S, MW-38S, and MW-42S (Table 3.45). All detections were below the MTCA Method B formula value for chloroform. Wells MW-29S, MW-35S, and MW-38S each contained detectable chloroform concentrations during every sampling event (MW-35S was installed in September 1995 and removed from the sampling program in July 1996; MW-38S was installed in April 1996).

The highest concentrations were detected in well MW-29S during every sampling event except December 1995. Well MW-41S contained the highest chloroform concentrations during December 1995. The majority of detections occurred in wells MW-29S, MW-35S, MW-38S, and MW-42S, hydraulically downgradient from Zone A. These results indicate that the source of chloroform in offsite groundwater is related to Zone A. However, the presence of chloroform in well MW-36S during the 2nd, 3rd, and 4th Quarter 1996 sampling events indicates that there may also be some lesser contribution from the Municipal Landfill.

- Methylene chloride was detected in offsite groundwater during two of the eight sampling events (December 1995 and September 1996); all detections were well below the MTCA Method B formula value (Table 3.45). Methylene chloride was detected in one Offsite Well (0.33 in MW-33S) during December 1995, but was detected in seven out of nine Offsite Wells (MW-32S, MW-33S, MW-36S, MW-37S, MW-38S, MW-40S, and MW-42S) sampled during September 1996. The concentrations observed during September 1996 ranged between 1 µg/L and 1.4 µg/L. Methylene chloride was not detected in offsite groundwater during any other sampling events. The source of methylene chloride in offsite groundwater during December 1995 and September 1996 is unclear. However, it was detected groundwater samples from both Zone A and Landfill Wells during Phase II RI sampling and its occurrence in wells MW-32S, MW-33S, and MW-38S during September 1996 indicated that it may be related to both Zone A and the Municipal Landfill.

Three ketones (acetone, 2-butanone, and 2-hexanone) were detected in groundwater from Offsite Wells. Ketone distributions in offsite groundwater can be described as follows:

- Acetone was detected in offsite groundwater during two sampling events (June and September 1995). Acetone was detected in Offsite Wells MW-29S, MW-31S, and MW-32S at concentrations ranging between 0.17 and 0.97 µg/L during June 1995, and was detected at 0.32 and 0.37 µg/L in wells MW-32 and MW-30S, respectively during September 1995. Each of the detections was well below the MTCA Method B formula value of 800 µg/L for acetone. The source of acetone in offsite groundwater is unclear.
- 2-butanone was only detected in one sample from the Offsite Wells (2.3 µg/L in the June 1995 sample from well MW-29S), while 2-hexanone was detected in two samples (the June 1995 samples from wells MW-31S and MW-32S). Both were below the MTCA Method B formula value (Table 3.45). The source of 2-butanone and 2-hexanone in offsite groundwater is unclear; however, each of the detected concentrations was well below the MTCA Method B formula value.

Benzene, chlorobenzene, and toluene, ethylbenzene, and xylenes were each detected in offsite groundwater at concentrations below the laboratory's practical quantification limits. A description of their distributions in groundwater follows:

- Toluene was detected in three Offsite Wells during the October 1995 sampling event but was not detected in offsite groundwater during any other sampling event. Each of these detections was well below the MTCA Method B formula value for toluene.
- Benzene was detected in three samples from the Offsite Wells: the June 1995 samples from wells MW-29S and MW-30S, and the October 1995 duplicate sample from well MW-35S (benzene was not detected in the primary sample). One sample, the duplicate sample from well MW-35S, was above the MTCA Method B formula value for benzene

(Table 3.45). However, because benzene was not detected in the primary sample from MW-35S (or any other sample during October 1995), and was not detected in any other sample from MW-35S, and because the reported value was below the laboratory's practical quantification limits, this detection is not considered to be representative of groundwater conditions in well MW-35S.

- Chlorobenzene was only detected in one sample from the Offsite Wells: the June 1995 sample from well MW-30S. Chlorobenzene in this sample was reported at an estimated concentration of 0.044 µg/L, well below the MTCA Method B formula value of 1,600 µg/L for chlorobenzene.

Two additional compounds (1,2-dichloropropane and vinyl acetate) were detected in offsite groundwater. The compound, 1,2-dichloropropane, was detected in groundwater samples from Offsite Wells MW-30S, MW-31S, MW-34S, and MW-37S. Each of these detections was below the MTCA Method B formula value for 1,2-dichloropropane. Its occurrence in wells MW-30S, MW-31S, MW-34S, and MW-37S without being detected in wells MW-29S or MW-35S indicates that the presence of 1,2-dichloropropane in offsite groundwater is associated with the Municipal Landfill.

Vinyl acetate was only detected in one well (MW-29S) and during only one sampling event (June 1995). During this event vinyl acetate was detected at 0.053 µg/L, approximately one half the analytical detection limit (0.1 µg/L). Examination of the laboratory data resulted in identification of this detection as a false positive by the analytical laboratory and project data validation team. Vinyl acetate has never been detected in any other well at the site.

3.13.2 INDICATOR COMPOUNDS

Chemical contour maps were generated for the six indicator compounds (PCE, TCE, 1,1-DCE, cis-1,2-DCE, 1,2-DCA, and vinyl chloride) to provide an illustration of the extent of impacted groundwater associated with the site (Figures 3-72 and 3-119). The chemical concentration contour maps for the selected indicator compounds suggest the presence of one or more plumes of VOC-impacted groundwater extending downgradient (south-southwest) from the site. In addition, the data indicate that VOC concentrations in groundwater are consistently elevated in at least two areas: (1) the area around the west side and southwest corner of Zone A, and (2) along the west side of the Municipal Landfill.

The highest concentrations of each of the six indicator compounds were detected either in well EE-3, adjacent to the southwest corner of Zone A, or along a relatively narrow linear pathway extending from south-southwest Zone A. An exception to this is PCE, which was detected at its maximum concentration (14 µg/L) in both well EE-3, adjacent to Zone A, and in well #4 along the western boundary of the Municipal Landfill during March 1996.

Although the concentrations of VOCs varied somewhat from one sampling event to the next, the overall shape of the map contours remained similar, suggesting that the source(s) may be releasing chemicals to groundwater at a near steady rate.

Contour maps show similar distributions for TCE, PCE, and cis-1,2-DCE. These contaminants appear to exhibit a greater horizontal distribution in offsite groundwater than the other indicator compounds.

Similar distributions are also observed in the chemical contour maps for 1,1-DCE, 1,2-DCA, and vinyl chloride. These compounds tend to occur as two or more distinct plumes.

Each of the six indicator compounds was detected in at least one of the furthest downgradient offsite wells (MW-40S, MW-41S, and MW-42S). PCE, TCE, and cis-1,2-DCE were each detected in MW-40S, MW-41S, and MW-42S, although PCE was the only compound above MTCA Method B formula values in MW-42S, the well located furthest downgradient from the site.

Of all the indicator VOCs, 1,2-DCA shows the most variation between sampling events. For example, 1,2-DCA was generally present across the site in June 1995, but occurred only in wells adjacent or downgradient from Zone A or along the western boundary of the Municipal Landfill during subsequent sampling events. In the September 1995 event, 1,2-DCA was present in wells along the western boundary of the Municipal Landfill and wells further downgradient and southwest of Zone A, but was not detected in the wells closest to the west side and southwest corner of Zone A. In the March 1996 event, 1,2-DCA was not detected in wells along the western boundary of the Municipal Landfill, but was detected in wells downgradient and southwest of Zone A. The highest concentration of 1,2-DCA in groundwater was 83 µg/L at well EE-3, during the July 1996 event.

3.13.3 SEMI-VOLATILE ORGANIC COMPOUNDS

A total of 11 SVOCs (benzyl alcohol, 1,2,4-trichlorobenzene, naphthalene, 4-chloro-3-methyl phenol, 2-methyl naphthalene, 2-nitroaniline, dimethyl phthalate, 2,6-dinitrotoluene, acenaphthene, di-n-butyl-phthalate, and butyl benzyl phthalate) were detected in offsite groundwater during the Phase II sampling. The majority of these detections were below the laboratory's practical quantification limits and were listed as estimated concentrations. Four SVOCs (2,6-dinitrotoluene, 2-nitroaniline, 4-chloro-3-methylphenol, and butyl benzylphthalate) were only detected during the 3rd Quarter 1995 sampling event. Three SVOCs (1,2,4-trichlorobenzene, 2-methylnaphthalene, and acenaphthene) were only detected during the 4th Quarter 1995 sampling event. The remaining four SVOCs were detected in at least one Offsite Well during both the 3rd Quarter 1995 and 1st Quarter 1996 sampling events.

Eleven of the 14 Offsite Wells contained at least one SVOC during the Phase II investigation; however, of the 11 SVOCs, none were detected in the same well on more than one occasion (Table 3.46), and no trend in the distribution of SVOCs in offsite groundwater was observed. The concentrations of each of the SVOCs detected in the Offsite Wells were all well below their respective MTCA Method B formula values. Together, these results indicate that offsite groundwater has not been significantly impacted by SVOCs migrating from the site.

3.13.4 APPENDIX I METALS

Three WAC 173-351-990 Appendix I Metals (arsenic, lead, and beryllium) were detected above their MTCA Method B formula values in groundwater samples collected from Offsite Wells (Table 3.46). Arsenic was detected in 25 of the 28 samples collected from the Offsite Wells during the Phase II investigation. However, arsenic was detected in 191 out of a total of 219 samples collected across the site during the Phase I and II investigations. Each of these detections was above the MTCA Method B formula value for arsenic (0.05 µg/L), with the highest concentrations detected in the June 1995 sample from well MW-19S (8.8 µg/L) and the April 1996 sample from Offsite Well MW-38S (8.9 µg/L). Arsenic was detected above the MTCA Method B formula value in 14 of the 15 samples collected from upgradient background wells NW-5, MW-20S, and MW-28S. The general occurrence of arsenic across the site, as well

as in upgradient and offsite wells, indicates that its presence in groundwater is not related to site activities.

Beryllium has only been detected in one sample from the Offsite Wells: the duplicate sample collected from well MW-35S during October 1995. The fact that beryllium was not detected in the primary sample from this well and has not been detected in any other sample from the Offsite Wells indicates that its presence is not the result of site activities.

Lead was detected in 8 of the 28 samples collected from Offsite Wells during Phase II sampling (Table 3.47). Of the eight detections, three exceeded the MTCA Method A criteria of 5 µg/L for lead: the 3rd Quarter 1995 samples from wells MW-33S and MW-35S (both the primary and duplicate samples). However, lead concentrations in groundwater have varied significantly throughout the course of groundwater monitoring at the site. For example, lead was only detected in 1 of the 32 wells sampled during June 1995 (2 µg/L in well #8), but was detected in all 42 wells sampled during September and October 1995 including all upgradient, background, and offsite wells. Lead concentrations exceeded the MTCA Method A criteria in 19 of the 42 wells sampled during September and October 1995, including 8.6 µg/L in upgradient well NW-5, but were below detection limits in each of the same 42 wells during December 1995. Lead was detected in 6 of the 45 wells sampled during March 1996 (all below the Method A value) and in 4 of the 21 wells sampled during July 1996 with one above the MTCA Method A value (13 µg/L in EE-3).

No clear trend in the lead data was identified. However, it is interesting to note that groundwater elevations across the site were at their lowest during September 1995 when lead was detected in all 42 wells. This observation, coupled with the high degree of variability in the number of detections and concentrations of lead in groundwater over the course of Phase II sampling, as well as its occurrence in upgradient and background wells, indicates that its presence is not related to site activities.

3.13.5 APPENDIX II METALS

WAC 173-351-990 Appendix II metals include calcium, magnesium, iron, manganese, potassium and sodium. Calcium, magnesium, potassium, and sodium were each detected in all samples collected from the Offsite Wells (Table 3.48). The highest concentrations of each of

these four compounds were detected in the April 1996 sample from well MW-39S. Calcium concentrations ranged from 58,400 µg/L in well MW-33S (October 1996) to 88,700 in MW-39S (July 1996) µg/L. Magnesium concentrations ranged from 18,700 µg/L to 27,800 µg/L with the lowest concentration occurring during April 1996 in well MW-38S and the highest occurring in well MW-39S during the same sampling event.

Potassium concentrations ranged between 7,030 µg/L and 10,400 µg/L. The lowest potassium concentrations were measured in well MW-30S during December 1995. The highest potassium concentration was detected in well MW-39S during April 1996. Sodium was detected at concentrations ranging from a low of 31,000 µg/L in well during December 1995 and 45,900 µg/L in well MW-39S during April 1995.

Iron was only detected in four samples from the Offsite Wells. The two highest concentrations (702 µg/L in well MW-30S and 387 µg/L in well MW-32S) were both detected during the December 1995 sampling event. The other two detections occurred in wells MW-31S (µg/L) and MW-36S (45.9 µg/L) during April 1996. Manganese was only detected in one sample from the Offsite Wells: 8.6 µg/L in the April 1996 sample from well MW-38S.

3.13.6 WATER QUALITY PARAMETERS

The term water quality parameters in this report is used in reference to the following list of parameters: bicarbonate or carbonate alkalinity (as CaCO₃), chloride, sulfate, total alkalinity (as CaCO₃), ammonia (as N), total organic carbon (TOC), total dissolved solids (TDS), chemical oxygen demand (COD), nitrate (as N), and nitrite (as N).

Bicarbonate/alkalinity concentrations have remained relatively consistent in offsite groundwater throughout the course of Phase II RI and Post-RI monitoring. Bicarbonate/alkalinity in the Offsite Wells levels ranged from 153 to 231 mg/L (as CaCO₃). The highest levels of bicarbonate/alkalinity were consistently detected in well MW-31S with levels ranging between 225 mg/L (as CaCO₃) and 231 mg/L (as CaCO₃) (Table 3.49).

As with bicarbonate concentrations, there has been little variation in the concentrations of chloride and sulfate over the course of Phase II RI and Post-RI monitoring, and concentrations of these compounds have been relatively consistent in the Offsite Wells. Chloride in offsite groundwater varied from 24.2 to 49.9 mg/L; sulfate concentrations in offsite groundwater ranged

from 70 to 102 mg/L. The highest concentrations of chloride and sulfate both occurred in well MW-39S during July 1996. The July 1996 sample from MW-39S also contained the highest concentrations of nitrate (22.1 mg/L as N) and total dissolved solids (530 mg/L). With the exception of the July 1996 sample from well MW-39S, nitrate concentrations measured in the Offsite Wells fell in a relatively narrow range, between 7.95 mg/L (as N) and 15.9 mg/L (as N). No nitrite was detected in any of the Offsite Wells.

TOC concentrations were only above detection limits in one sample from the Offsite Wells: the December 1995 sample from well MW-29S. COD levels in offsite groundwater ranged from less than the detection limit (10 mg/L) to 18 mg/L. The highest COD levels were reported in wells MW-37S and MW-38S during September 1996 event. The September 1996 sample was the only sample from well MW-37S that contained measurable COD levels; well MW-38S contained detectable COD concentrations during July 1996 and September 1996.

Ammonia was detected in a total of fifteen samples from the Offsite Well. Of the fifteen detections, five occurred during December 1995, while six occurred during July 1996. March 1996, with two detections, was the only other sampling event with more than one detection.

3.13.7 FIELD PARAMETERS

Prior to collection of groundwater samples, each well was purged using low flow techniques to ensure that samples were representative of groundwater conditions in the area surrounding the well screen. Dissolved oxygen (DO), pH, temperature, turbidity and oxygen-reduction potential (ORP) measurements were collected continuously while purging the well and continued readings stabilized to within ten percent.

A discussion of the variations in the field parameters observed in offsite groundwater (Table 3.50 is described below:

- DO measurements collected from the Offsite Wells ranged from a low of 3.9 mg/L in well MW-42S during the 3rd Quarter 1996 sampling event to a high of 8 mg/L in well MW-36S during the 1st Quarter 1997 sampling event. In general, the lowest DO concentrations occurred in Offsite Wells MW-42S, MW-29S, MW-41S, and MW-37S, while wells MW-32S, MW-33S, MW-36S, and MW-38S generally contained the highest DO concentrations.

- ORP values in the Offsite Wells ranged from a low of 77 mV in well MW-29S during the 1st Quarter 1996 sampling event to a high of 251 mV in well MW-35S during the 2nd quarter 1996 sampling event. Although all ORP measurements indicated oxidative conditions, ORP readings were highly variable from well to well and from quarter to quarter within the same well. For instance, while well MW-29S contained the lowest ORP value measured in the Offsite Wells, it also exhibited ORP measurements in excess of 200 mV during the 1st Quarter 1996 and 1st quarter 1997 sampling events. Likewise, ORP was measured at 80 mV in well MW-36S during the 3rd Quarter 1996 sampling event, but exceeded 200 mV during the 2nd Quarter 1996 and 1st Quarter 1997 sampling events.
- Turbidity values were consistently below 2.5 ntu in the Offsite Wells with the lowest value (0.02 ntu) measured in well MW-33S during the 3rd Quarter 1996 and the highest value (2.24 ntu) occurring in well MW-37S during the 1st Quarter 1997.
- pH values in the Offsite Wells ranged between approximately 7 and 8.3 throughout the course of Phase II RI and Post-RI sampling.

4 CONCLUSIONS

4.1 SOIL CHEMISTRY

No constituents were detected in site soils above their respective MTCA Method B formula values during either Phase I or Phase II sampling.

4.2 GROUNDWATER CHEMISTRY

Conclusions based on groundwater monitoring data generated from 6 quarterly sampling events from 54 wells at the Pasco Landfill site can be summarized as follows:

- No herbicides, pesticides, dioxins, or SVOCs were detected above MTCA Method B formula values in any Phase I or II RI groundwater samples collected from site.
- Five WAC 173-351-990 Appendix I Metals (arsenic, lead, antimony, beryllium, and thallium) were detected above their MTCA Method B formula values in groundwater samples collected from the site. Arsenic was detected above the MTCA Method B formula value in 191 out of a total of 219 samples collected during the Phase I and II investigations. Arsenic was also detected above the MTCA Method B formula value in 14 of the 15 samples collected from upgradient and background wells, as well as 26 of the 29 samples collected from Offsite Wells MW-29S through MW-42S during the Phase II investigation. The general occurrence of arsenic across the site, as well as in upgradient wells, indicates that its presence in groundwater is not related to site activities.
- Lead concentrations in groundwater have varied significantly throughout the course of groundwater monitoring at the site. Lead was detected in 10 of the 28 wells sampled during the Phase I investigation; however, only 2 wells exceeded MTCA Method A formula value (5 µg/L). Lead was detected in only 1 of the 32 wells sampled during June 1995 (2 µg/L in well #8), but was detected in all 42 wells sampled during September and October 1995, including all upgradient, background, and offsite wells. Of the 42 detections, 19 exceeded the MTCA Method A value, including upgradient well NW-5 (8.6 µg/L). Lead was not detected in any wells during December 1995, but was detected in 6 wells sampled during March 1996 (all below the Method A formula value), and in 4 of the 21 wells sampled during July 1996 [one exceeded the MTCA Method A value (13 µg/L in EE-3)].

No clear trend in the lead data has been identified; however, it is interesting to note that groundwater elevations across the site were at their lowest during September 1995 when lead was detected in all 42 wells. This observation, coupled with the high degree of variability in the number of detections and the concentrations detected in groundwater over the course of Phase II and I sampling, as well as its occurrence in background wells,

indicates that the presence of lead in groundwater is not the result of waste handling practices at the site.

- The antimony data have exhibited a high degree of variability over the course of Phase II sampling with detections in 1 sample during the 2nd Quarter 1995, 13 samples during the 3rd Quarter 1995, none during the 4th Quarter 1995 or 1st Quarter 1996 sampling events, and 21 of 21 samples analyzed during the 2nd Quarter 1996 sampling event. Only 9 wells contained antimony more than once; no wells contained antimony more than twice. Only 4 samples contained antimony concentrations above the MTCA Method B formula value. Well EE-3 was the only well that exceeded the Method B formula value more than once. Together, the high degree of variability in the number of detections and the concentrations of antimony detected in groundwater at the site, as well as its occurrence upgradient and background wells over the course of Phase II sampling, indicates that its presence is not the result of waste handling practices at the site.
- Beryllium was detected in three wells (#4, #5, and MW-15S) during the Phase I field investigation, and twice during Phase II investigation: the duplicate sample from Offsite Well MW-35S during October 1995 (beryllium was not detected in the primary sample), and the July 1996 sample from well EE-3. Beryllium has not been detected in any well on more than one occasion.
- Thallium was detected a total of six times during Phase I and II sampling, with concentrations exceeding the MTCA Method B formula value in a total of five samples from four wells: EE-5 in February 1993 and September 1995; wells #1, #9, and EE-5 in September 1995; and well EE-3 in July 1996. Well EE-5 was the only well that contained thallium on more than one occasion.

No clear trend in thallium concentrations was observed; however, the majority of detections occurred during the September 1995 sampling event which corresponds to the lowest water levels observed at the site. The July 1996 sample from well EE-3, which contained the highest thallium concentrations observed at the site, also contained the highest lead, antimony, beryllium, and antimony concentrations at the site, and the lowest pH and dissolved oxygen values observed in well EE-3.

In any event, the degree of variability in the number of detections and concentrations of beryllium and thallium in groundwater at the site indicates that their presence is not the result of site activities, although there may be some relationship between their occurrence and localized changes in groundwater geochemical or natural background conditions.

- A total of 20 VOCs have been detected above MTCA Method B formula values in groundwater at the site. Of these, six compounds (PCE, TCE, 1,1-DCE, 1,2-DCA, 1,1,2-trichloroethane, and vinyl chloride) have been detected above Method B cleanup levels in downgradient wells located at the site boundary.

These findings indicate that VOCs are the only constituents which have impacted groundwater above MTCA Method B formula values at the Pasco Sanitary Landfill Site. For

this reason, conclusions concerning the nature and extent of contamination at each zone, presented below, are focused on VOCs.

4.3 MUNICIPAL LANDFILL

Conclusions based on site characterization activities at the Municipal Landfill can be summarized as follows:

- The presence of methane and carbon dioxide above ambient atmospheric concentrations, accompanied by reduced oxygen concentrations observed in landfill gas probes, indicates that wastes in the Municipal Landfill are undergoing biodegradation.
- The highest methane and VOC concentrations occur in landfill gas probe clusters LFG-01 and LFG-02, along the western boundary of the Municipal Landfill and LFG-04 at the southeast corner of the Municipal Landfill. The lowest concentrations of methane, carbon dioxide, and VOCs were consistently found in LFG-03 at the southern tip of the Municipal Landfill.
- A total of 34 VOCs were detected in landfill gas samples collected from the site. Twenty-three of these VOCs were also detected in groundwater from both Landfill Wells and Zone A Wells.
- The highest concentrations of VOCs were detected in wells #4, MW-16S, and MW-23S along the western boundary of the Municipal Landfill.
- Eight VOCs (PCE, TCE, 1,1-DCE, 1,2-DCA, 1,2-dichloropropane, 1,4-dichloropropane, acrylonitrile and vinyl chloride) were detected above Method B cleanup levels in Landfill Wells. Of these, all eight exceeded MTCA Method B formula values in well #4, seven exceeded Method B in MW-16S, five were above Method B in MW-23S, and two exceeded Method B in well #9.

These data indicate that VOCs from waste in the former Municipal Landfill are impacting groundwater. In addition, a landfill gas plume containing VOCs has extended beyond the boundaries of the Municipal Landfill and may be impacting other areas at the site.

4.4 ZONE E AND ZONE TS-1/SL-1

Conclusions based on site characterization activities at Zone E and Zone TS-1/SL-1 can be summarized as follows:

- The results of the geophysical investigation at Zone E and TS-1/SL-1 indicate that the location of the buried waste in Zone E corresponds with the location reported in the

closure survey. The results of the EM-31 apparent conductivity survey revealed the presence of a low amplitude conductivity anomaly in the center of Zone TS-1/SL-1.

- The results of the bulk waste characterization activities indicate that Zone E is fully covered by a vegetated soil cap and plastic liner. Waste characterization analyses indicate that the waste present in Zone E would not be designated as either a characteristic RCRA hazardous waste or a characteristic Washington Dangerous Waste if it were excavated from the unit and indicate that the waste does not pose a threat to human health and the environment.
- No hexavalent chromium was detected in any samples collected from soil borings B-17 or B-18. Total chromium concentrations ranged from approximately 5 to 8 µg/L, indicating that the soil in the vicinity of the conductivity anomaly in Zone TS-1/SL-1 is not a likely source of chromium in wells EE-8 and MW-19S.
- Six additional samples were collected from Zone E during May 1996 and analyzed for total chromium, hexavalent chromium, VOCs, and VOCs by TCLP to assess the waste in Zone E as a potential source of VOCs in well MW-27S and chromium in wells and wells MW-19S and EE-8. The analyses for hexavalent chromium were negative. Total chromium was detected at concentrations ranging between 4.73 and 6.6 mg/kg, well below the MTCA Method B formula values of 80,000 for trivalent chromium and 400 mg/kg for hexavalent chromium in soil.
- No hexavalent chromium or mercury was detected in any Zone E Wells. Total chromium was below MTCA Method B formula value in all Zone E Wells.
- A southerly groundwater gradient was observed in the area of the Zone E Wells.
- Zone E is located adjacent to the former Municipal Landfill. No landfill gas probes or groundwater monitoring wells are located adjacent to the northeastern portion of the Municipal Landfill (due north of Zone E) to provide hydrostatic potential or chemical data for assessing this area as a potential source of VOCs in groundwater beneath Zone E.
- The analyses of the material collected from Zone E for VOCs by TCLP were negative. Four VOCs (1,2,4-Trichlorobenzene, PCE, chloroform, and toluene) were in the total VOC analyses of the Zone E waste material. Of the four VOCs detected in Zone E waste samples, three (PCE, chloroform, and toluene) have also been detected in the Zone E groundwater wells. However, analysis of analytical data indicates that the presence of these compounds in groundwater is not related to Zone E.
- A total of 21 VOCs were detected in Zone E Wells. Eighteen of the 21 VOCs detected in Zone E Wells were also detected in landfill gas samples. Twenty of the 21 VOCs detected in Zone E Wells were detected in well MW-27S. Nineteen of the 21 VOCs detected in Zone E Wells during Phase II sampling were also detected in Landfill Wells. Landfill Well #9 was used to provide chemical characterization data for groundwater impacted by the Municipal Landfill (west and northwest of Zone E). Seventeen of the 20 VOCs detected in well MW-27S were detected in Landfill Well #9 (Table 3-18).

- Four VOCs (1,1-DCE, carbon tetrachloride, 1,2-DCA, and PCE) were detected above MTCA Method B formula values in well MW-27S (Table 3-19); one (1,1-DCE) was detected above the MTCA Method B formula value in well MW-19S.
- Six chlorinated ethenes (PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride) were detected in Zone E Wells during Phase II sampling. Two of the six (PCE and 1,1-DCE) were detected in excess of MTCA Method B formula values. The compound 1,1-DCE is a biotransformation products of PCE and TCE. PCE and TCE were detected in all thirteen Landfill Wells during all sampling events. PCE was above the Method B formula value in all Landfill Wells, including well #9, during every Phase II sampling event.

The consistently higher concentrations of PCE, TCE, and their biotransformation products in Landfill Well #9 indicate that the presence of these chlorinated ethenes in groundwater are the result of hydraulic transport from sources located in the northeast portion of the Municipal Landfill and not related to Zone E. The higher TCE and 1,1-DCE concentrations found in MW-19S as compared with MW-27S are also inconsistent with hydraulic transport from Zone E, and provide supporting evidence for a source in the Municipal Landfill.

- Four chlorinated ethanes (1,1,1-TCA, 1,2-DCA, 1,1-DCA, and chloroethane) were detected in Zone E Wells during Phase II sampling. The consistently higher concentrations of 1,1,1-TCA, 1,1-DCA, and chloroethane in well MW-19S as compared to MW-27S, as well as the occurrence of 1,2-DCA and chloroethane in background wells, indicate that their presence in groundwater is not associated with Zone E, but may be the result of hydraulic transport from the Municipal Landfill.
- Five chlorinated methanes [trichlorofluoromethane, carbon tetrachloride (tetrachloromethane), chloroform (trichloromethane), methylene chloride (dichloromethane), and chloromethane] were detected in groundwater samples from Zone E Wells. The analysis of data for chlorinated methanes indicates that the presence of methylene chloride and chloromethane are not related to Zone E, but may be related to an upgradient source in the Municipal Landfill. Carbon tetrachloride, the only chlorinated methane above MTCA Method B formula values, was only detected in one sample; its source is unclear. The results for trichlorofluoromethane and chloroform are also inconclusive, although they provide some evidence for a potential source in the Municipal Landfill.
- Two ketones (acetone and 2-hexanone) were detected in groundwater from Zone E Wells. All but two detections (acetone in wells MW-19S and MW-27S) occurred during the June 1995 sampling event. Each of the detections was well below MTCA Method B formula values. Acetone was detected in one Zone E Well (EE-8) during the June 1995 sampling event and in wells MW-19S and MW-27S (June and September 1995), but was also detected in upgradient wells MW-20S, MW-28S, and NW-5 during June 1995, indicating that its presence in groundwater is not associated with Zone E.

The compound 2-hexanone was detected in Zone E Wells EE-8, MW-19S, and MW-27S during the June 1995 sampling event, but was not detected in any Zone E Wells during any subsequent sampling events. The compound 2-hexanone was also detected in

Landfill Well #9 during June 1995, indicating that its presence in groundwater is not associated with Zone E.

- Benzene and toluene were each detected in groundwater from Zone E Wells during the June 1995 sampling event, but were not detected during subsequent sampling events. Each of the detections was well below the MTCA Method B formula values. Benzene was detected at 0.03 µg/L in well MW-27S during the June 1995 sampling event, but was also detected at 0.3 µg/L in Landfill Well #9 and at 0.4 µg/L in upgradient background well MW-28S, indicating its presence is not associated with Zone E.

Likewise, toluene was detected in Zone E Wells EE-8 and MW-27S during June 1995, but was detected at higher concentrations in upgradient wells MW-20S, MW-28S, and NW-5, as well as Landfill Well #9, during this same event. Toluene was not detected in any of these wells during subsequent sampling events. The results indicate that toluene in groundwater is not associated with Zone E.

Together, the results of the Phase II Bulk Waste Characterization Analyses, the results of the additional Zone E waste profiling analyses conducted during May 1997, and the results of groundwater characterization indicate that the bulk waste material present in Zone E is not acting as a significant source of VOCs or chromium in groundwater.

Given the unknown location(s) of contaminant source areas within the Municipal Landfill, the southerly hydraulic gradient in the area of Zone E, and the high degree of similarity in VOCs detected in Landfill Well #9 and Zone E Well MW-27S, hydraulic transport or migration of VOCs from a dense vapor plume emanating from the northeastern portion of the Municipal Landfill appear to represent a potential sources of VOCs in well MW-27S.

4.5 ZONES C AND D

Conclusions based on site characterization activities at Zones C and D can be summarized as follows:

- The results of the geophysical investigation at Zones C and D indicate that the location of the buried waste corresponds with the location reported in the closure survey.
- Bulk Waste Characterization activities indicate that Zones C and D are fully covered by vegetated soil caps and plastic liners. Three VOCs (1,2-DCA, MEK, and TCE) were detected in the TCLP analysis of material from Zone D. MEK was the only VOC detected in the TCLP analysis of material from Zone C. Due to the presence of 1,2-DCA in the TCLP extract, at least a portion of the material present in Zone D would designate as both a RCRA hazardous waste and a Washington Dangerous

Waste if excavated from the unit. The waste samples from Zone C would not designate as either a characteristic RCRA hazardous waste or a characteristic Washington Dangerous Waste.

- Six VOCs (acetone, 2-butanone, 4-methyl-2-pentanone, toluene, m,p-xylenes, and o-xylenes) were detected in soil samples collected from beneath the zones in borings B-19 and B-20, all below their MTCA Method B formula values. Acetone and 2-butanone (MEK) were the only VOCs detected in soil samples below 35 feet bgs. None of the six VOCs detected in borings B-19 and B-20 were present above their respective MTCA Method B formula values in groundwater from Zone C and D Wells.
- The compound 1,1-DCE forms as a result of dehalogenation of TCE during anaerobic or methanogenic degradation. Neither 1,1-DCE nor any of the other potential biotransformation products of TCE (cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride) were detected in any of the soil or material samples collected from Zones C and D. Based on these results, it does not appear that the soil or material present in Zone C and D are acting as the sources of 1,1-DCE or PCE in groundwater.
- Zones C and D are located adjacent to, and hydraulically downgradient from, the southern boundary of the Municipal Landfill. Each of the 20 VOCs detected in Zone C and D Wells during Phase II sampling was also detected in Landfill Wells; 18 of the 20 were detected in landfill gas; and 15 of the 20 were detected in upgradient Landfill Wells #8 or #9.
- Six chlorinated ethenes (PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride) were detected in Zone C and D Wells during Phase II sampling (Table 3.24). Two compounds (PCE and 1,1-DCE) were detected above MTCA Method B formula values (Table 3.25) in Zone C and D Wells. A comparison between the concentrations of these compounds in upgradient wells #8 and #9 and Zone C and D Wells (Table 3.24) shows that, the concentrations of chlorinated ethenes are consistently higher in wells #8 and #9. The consistently higher concentrations of PCE, TCE and their biotransformation products in upgradient Landfill Wells #8 and #9 indicate that the presence of these VOCs in groundwater beneath Zones C and D are the result of hydraulic transport from the Municipal Landfill.
- Four chlorinated ethanes (1,1,1-TCA, 1,2-DCA, 1,1-DCA, and chloroethane) were detected in Zone C and D Wells during Phase II sampling. Only two (1,2-DCA and 1,1-DCA) were detected in Zone C and D Wells EE-6 and EE-7, while each of the four compounds were detected in well MW-18S and upgradient Landfill Well #9. Wells EE-6 and EE-7 are located closer to, and hydraulically downgradient from, Zones C and D. For this reason wells EE-6 and EE-7 are expected to intercept any potential contaminants migrating from Zones C and D. Therefore, the presence of chlorinated ethanes (1,1,1-TCA, 1,2-DCA, 1,1-DCA, and chloroethane) do not appear to be related to Zones C and D, but may be the result of hydraulic transport from the Municipal Landfill (Figure 3-50).

- Four chlorinated methanes [trichlorofluoromethane, chloroform (trichloromethane), methylene chloride (dichloromethane), and chloromethane] were detected in groundwater samples from Zone C and D Wells. Only two (methylene chloride and chloromethane) were detected in Zone C and D Wells EE-6 or EE-7, while each of the four VOCs were detected in well MW-18S. Again, wells EE-6 and EE-7 are located closer to, and hydraulically downgradient from, Zones C and D and are expected to intercept any potential contaminants migrating from Zones C and D. Therefore, as with chlorinated ethanes, the presence of chlorinated methanes do not appear to be related to Zones C and D, but may be the result of hydraulic transport from the Municipal Landfill (Figure 3-50).
- Three ketones (acetone, 2-butanone, and 2-hexanone) were detected in groundwater from Zone C and D Wells with all but one detection (acetone in well MW-18S) occurring during one sampling event (June 1995). In addition, the presence of acetone, 2-butanone, and 2-hexanone in upgradient wells at similar concentrations and during the same sampling events as they were detected in Zone C and D Wells, indicate that their presence in groundwater is associated with an upgradient source in the Municipal Landfill.
- Toluene, ethylbenzene, and xylenes were each detected in groundwater during the June 1995 sampling event. None of these compounds was detected during subsequent sampling events. Each of the detections was well below the MTCA Method B formula values for toluene and xylenes. Toluene was detected in all three Zone C and D Wells as well as upgradient wells MW-28S and NW-5 and Landfill Well #9 during the June 1995 sampling event. The highest toluene concentrations were observed in upgradient well NW-5 and Landfill Well #9, indicating that Zones C and D are not the source of toluene in groundwater.
- Ethylbenzene and xylenes were each detected in Zone C and D Well EE-7 in June 1995, but were not detected in adjacent Landfill Wells #8 or #9. Each of these compounds was detected in the soil sample collected immediately beneath Zone C during Bulk Waste Characterization Activities (Table 3.21), although ethylbenzene was not detected in soil borings B-19 or B-20 (Figure 3-50 and Table 3.23). Although xylene concentrations in groundwater are below the MTCA Method B formula value, its presence in waste and soil samples from beneath the zones indicates a potential source in Zones C and D.
- Two additional VOCs (acrylonitrile and carbon disulfide) were detected in groundwater samples from Zone C and D Wells or upgradient wells. Acrylonitrile was only detected in one sample from Zone C and D Wells: the June 1995 sample from well MW-18S. Carbon disulfide was detected in three samples: the June 1995 sample from MW-18S and the March 1996 samples from wells EE-6 and EE-7. All detections of acrylonitrile and carbon disulfide in Zone C and D Wells were below MTCA Method B formula values.
- As with the ketones, the presence of carbon disulfide at similar concentrations in upgradient or Landfill Wells during the same sampling events as it was detected in Zone C and D Wells, indicates that its presence in groundwater is not associated with

Zone C and D. Acrylonitrile was only detected once in ground water in well MW-18S and never in Wells EE-6 or EE-7. Wells EE-6 and EE-7 are located closer to, and hydraulically downgradient from, Zones C and D. For this reason, wells EE-6 and EE-7 are expected to intercept any potential contaminants migrating from Zones C and D. Since acrylonitrile was only detected in ground water once, it is not possible to determine its source. However, because it was never detected in EE-6 or EE-7, its presence in groundwater does not appear to be associated with Zones C and D.

In summary, each of the 20 VOCs detected in Zone C and D Wells during Phase II sampling was also detected in Landfill Wells; 18 of the 20 were detected in landfill gas. The evaluation of the location, timing, and concentration of each detected VOC presented above indicates that their presence in groundwater, with the possible exception of xylenes, is not associated with Zones C and D but appears to be associated with the Municipal Landfill.

4.6 ZONES U-1 AND TS-2

These zones were adequately characterized during the Phase I RI. No additional scope of work was specified in the Enforcement Order. The results of the Phase I investigation indicate that these zones are not impacting groundwater.

4.7 LAGOONS SL-2 AND SL-3

These zones were adequately characterized during the Phase I RI. No additional scope of work was specified in Enforcement Order. Characterization of these zones indicate that they are not impacting groundwater.

4.8 SLUDGE MANAGEMENT AND LANDSPREAD AREAS

These zones were adequately characterized during the Phase I RI. No additional scope of work was specified in the Enforcement Order. The results of characterization activities indicate that these zones are not impacting groundwater.

4.9 ZONE B

Conclusions based on site characterization activities at Zone B can be summarized as follows:

- The results of the geophysical investigation at Zone B indicate that the location of the buried waste corresponds with the location reported in the closure survey.
- Drummed Waste Characterization activities indicate that Zone B was closed with a soil cap approximately three feet in thickness which is underlain by a plastic liner and an estimated three additional feet in of soil. Drummed Waste Characterization activities also indicate that the drums are likely in poor condition.
- No dioxin congeners were detected above MTCA Method B formula values in any Zone B soil samples, indicating that soil in the vicinity Zone B does not pose a threat to human health and the environment.
- A total of 21 VOCs were detected in either Zone B Wells or MW-25S. Fifteen of these VOCs were detected only during September 1995.
- No VOCs were detected above MTCA Method B formula values in Zone B Wells. One VOC (1,1-DCE) was detected above its MTCA Method B formula value in a single sample from upgradient offsite well MW-25S during the June 1995 sampling event.
- Three chlorinated ethenes PCE, TCE, and cis-1,2-DCE (a biotransformation product of PCE/TCE dehalogenation) were detected in Zone B Wells during June 1995. PCE, TCE, and 1,1-DCE were also detected in background wells during this event. None of these compounds were detected in any other samples from Zone B Wells.
- Three chlorinated ethanes (1,1,2-TCA, 1,2-DCA, and 1,1-DCA) were detected in Zone B wells during Phase II sampling (Table 3.33). The compound 1,1,2-TCA was detected in well MW-26S during the June and September 1995 sampling events, but has not been detected in any other Zone B Well. Likewise, 1,1,2-TCA biotransformation products (1,2-DCA, 1,1-DCA, and chloroethane) were also detected in Zone B Wells during June 1995, but have not been detected in any Zone B Wells during any other sampling event. Chloroethene and 1,2-DCA were detected at similar concentrations in upgradient wells and therefore do not appear to be associated with Zone B.
- 1,1,2-TCA and 1,1-DCA were detected only during one sampling event. Each detection was below the laboratory's practical quantification limits. Although the source of these compounds in groundwater is unknown, they do not appear to be associated with Zone B.
- Four chlorinated methanes [trichlorofluoromethane, chloroform (trichloromethane), methylene chloride (dichloromethane), and chloromethane] were detected in groundwater samples from Zone B Wells. Trichlorofluoromethane was detected at the same concentration in Zone B Well MW-26S and upgradient background well

MW-25S during the September 1995 sampling event, but was not observed in any Zone B Wells. Its presence in groundwater at the same concentrations in both upgradient and downgradient wells indicates that it is not associated with Zone B.

- Chloroform not detected in any Zone B Wells during any sampling event, but was detected in one sample from upgradient well MW-25S (0.022 µg/L during June 1995). For this reason, the presence of chloroform does not appear to be associated with Zone B.

Methylene chloride was detected in Zone B wells EE-4 and EE-5 during the September 1995 sampling event. Both samples contained comparable levels of methylene chloride in the associated method blank and were flagged as estimated concentrations by the data validation team. Methylene chloride was also detected in upgradient wells MW-25S and MW-28S during the June 1995 sampling event, but was not detected in any other samples from Zone B Wells, indicating that its presence in groundwater is either the result of a potential upgradient source or was introduced in the samples as a laboratory contaminant.

Chloromethane was detected in all Zone B wells, as well as upgradient background wells MW-25S, MW-28S, and NW-5, during June 1995 with the highest concentrations observed in upgradient well MW-25S. Chloromethane was not observed in any Zone B Wells during subsequent sampling events, indicating that its presence in groundwater is not associated with Zone B.

- Four ketones (acetone, 2-butanone, 2-hexanone, and 4-methyl-2-pentanone) were detected in Zone B Wells with the majority of detections occurring during the June 1995 sampling event. The presence of acetone and 2-butanone in upgradient wells during the same sampling events as it was detected in Zone B Wells indicates that its presence is not associated with Zone B.

2-Hexanone and 4-methyl-2-pentanone were each detected in June 1995. Neither compound was detected during any subsequent sampling event, indicating that its presence in groundwater is not associated with Zone B.

- Three additional VOCs (1,2-dichloropropane, toluene, and carbon disulfide) were detected in groundwater samples from Zone B Wells (Table 3.33). Toluene and 1,2-dichloropropane were only detected during one sampling event (June 1995). Toluene was also detected at higher concentrations in upgradient background wells, indicating that its presence in groundwater is not associated with Zone B. The source of 1,2-dichloropropane is unknown; however, its appearance during only one sampling event indicates that it is not related to Zone B.

Carbon disulfide was not detected in any Zone B Wells during the 2nd quarter 1995, but was detected in upgradient wells MW-25S and MW-28S. Carbon disulfide was detected in Zone B Wells EE-4 and EE-5 during the March 1996, but was also detected in upgradient well MW-25S during this same sampling event. Its occurrence in upgradient background wells indicates that the presence of carbon disulfide in groundwater is not associated with Zone B.

In summary, a total of 16 VOCs were detected in Zone B Wells with 14 of the 16 detected only during one sampling event (June 1995); 10 of the 16 VOCs detected in Zone B Wells were also detected in upgradient background wells during the same sampling event; and 3 are degradation products of VOCs detected in upgradient wells. Three compounds (1,1-TCA, 2-hexanone, and 4-methyl-2-pentanone) were not detected in upgradient wells. However, 2-hexanone and 4-methyl-2-pentanone were only detected during the June 1995 sampling event. Together, these data indicate that Zone B is not acting as a source of VOCs in groundwater.

4.10 ZONE A/NORTH-SOUTH BURN TRENCH/BALEFILL

Conclusions based on site characterization activities at Zone A, the North-South Burn Trench, and the Balefill Areas can be summarized as follows:

- The geophysical investigation was successful at identifying the location of the waste present in Zone A, the North-South Burn Trench, and the Balefill Areas.
- Drummed Waste Characterization activities indicate that Zone A is covered by a competent soil cap and plastic liner and that the drums are likely in poor condition.
- The presence of methane and carbon dioxide above ambient atmospheric concentrations, accompanied by the reduced oxygen concentrations observed in soil-gas probes indicate that anaerobic biodegradation is occurring beneath Zone A. This is supported by the low nitrate levels seen in EE-3.
- VOCs in soil-gas are elevated relative to background concentrations in the area surrounding Zone A.
- A total of 37 VOCs were detected in groundwater samples from Zone A Wells.
- Eighteen VOCs were detected above MTCA Method B formula values in groundwater samples from Zone A Wells.
- The highest concentrations of VOCs in site groundwater were detected in Zone A Well EE-3.

These results indicate that VOCs migrating from waste in Zone A are impacting groundwater at the site.

4.11 OFFSITE GROUNDWATER

The results of Phase I and II RI offsite groundwater characterization activities can be summarized as follows:

- No herbicides were detected in offsite groundwater.
- A total of eleven SVOCs (benzyl alcohol, 1,2,4-trichlorobenzene, naphthalene, 4-chloro-3-methyl phenol, 2-methyl naphthalene, 2-nitroaniline, dimethyl phthalate, 2,6-dinitrotoluene, acenaphthene, di-n-butyl-phthalate, and butyl benzyl phthalate) were detected in offsite groundwater during the Phase II sampling. The majority of these detections were below the laboratory's practical quantification limits and were listed as estimated concentrations. Eleven of the 14 Offsite Wells contained at least one SVOC during the Phase II investigation; however, of the eleven SVOCs, none were detected in the same well on more than one occasion. The concentrations of each of the SVOCs detected in the Offsite Wells were all well below their respective MTCA Method B formula values. Together, these results indicate that offsite groundwater has not been significantly impacted by SVOCs migrating from the site.
- Seven VOCs were detected above MTCA Method B cleanup levels in Offsite Wells. Five VOCs exceeded MTCA Method B cleanup levels in Offsite Wells MW-29S, MW-35S, MW-38S, and MW-41S with concentrations generally decreasing with lateral distance hydraulically downgradient to south-southwest from Zone A. PCE exceeded MTCA Method B cleanup levels in ten Offsite Wells and was the only compound present above MTCA Method B cleanup levels in well MW-42S, the furthest downgradient well.
- Three WAC 173-351-990 Appendix I Metals (arsenic, lead, and beryllium) were detected above their MTCA Method B formula values in groundwater samples collected from Offsite Wells. Arsenic was detected in 25 of the 28 samples collected from the Offsite Wells and in 191 of 219 samples collected across the site during the Phase I and II investigations. Each of these detections was above the MTCA Method B formula value for arsenic (0.05 µg/L). Arsenic was detected above the MTCA Method B formula value in 14 of the 15 samples collected from upgradient background wells NW-5, MW-20S, and MW-28S. The general occurrence of arsenic across the site, as well as in upgradient and offsite wells, indicates that its presence in offsite groundwater is not related to site activities.

Beryllium has only been detected in one sample from the Offsite Wells: the duplicate sample collected from well MW-35S during October 1995. The fact that beryllium was not detected in the primary sample from this well and has not been detected in any other sample from the Offsite Wells indicates that its presence is not the result of site activities.

Lead was detected in 8 of the 28 samples collected from Offsite Wells during Phase II sampling. Of the eight detections, three exceeded the MTCA Method A criteria. Lead concentrations in groundwater have varied significantly throughout the course of groundwater monitoring at the site. No clear trend in the lead data was identified;

however, it is interesting to note that groundwater elevations across the site were at their lowest during September 1995 when lead was detected in all 42 wells. This observation, coupled with the high degree of variability in the number of detections and concentrations of lead in groundwater over the course of Phase II sampling, as well as its occurrence in upgradient and background wells, indicates that its presence in offsite groundwater is not related to site activities.

The results of the Phase II RI and Post RI groundwater monitoring program indicate that VOCs in excess of MTCA Method B formula values are present in groundwater hydraulically downgradient from the site. In addition, analysis of the Phase II RI and Post RI groundwater monitoring data indicate that the presence of VOCs in offsite groundwater is related to releases from Zone A and the Municipal Landfill.

4.12 PROJECT STATUS

As a result of completing the Phase II RI, sufficient information has been collected, developed and evaluated regarding the extent and nature of contamination at the Pasco Landfill.

5 REFERENCES

- Bauer, H.H. and J.J. Vaccaro, 1990. Estimates of Groundwater Recharge to the Columbia Plateau Regional Aqiifer System, Washington, Oregon, and Idaho, for Predevelopment and Current Land-Use Conditions. US Geological Survey, Water-Resources Investigations Report 88-4108.
- Burlington Environmental Inc. 1994. Phase I Remedial Investigation, Pasco Landfill. March.
- Burlington Environmental Inc. 1995a. Phase II Remedial Investigation/Feasability Study, Pasco Landfill. Volume I, Work Plan. March.
- Burlington Environmental Inc. 1995b. Phase II Remedial Investigation/Feasability Study, Pasco Landfill. Volume II, Sampling and Analysis Plan. March.
- Burlington Environmental Inc. 1995c. Phase II Remedial Investigation/Feasability Study, Pasco Landfill. Volume III, Data Management Plan. March.
- Burlington Environmental Inc. 1995d. Phase II Remedial Investigation/Feasability Study, Pasco Landfill. Volume IV, Health and Safety Plan. March.
- Burlington Environmental Inc. 1995e. Phase II Remedial Investigation/Feasability Study, Pasco Landfill. Volume V, Public Participation Plan. March.
- Dietrich, Larry. 1993. Personal communication with Chip Goodhue and others. Burlington Environmental Inc. June 1, 2, and 3, 1993
- Dinicola, Richard S., 1997. Estimates of Recharge from Runoff at the Hanford Site, Washington. US Geological Survey, Water-Resources Investigations Report 97-4038.
- Fenn, D.G., K.J. Hanley, and T.Z. DeGeare. 1975. Uses of the Water Balance Method for Predicting Leachate Generation from Solid Waste Disposal Sites. EPA/530/SW-168.
- Gephart, R.E., R.C. Arnett, R.G. Baca, L.S Leonhart, F.A. Spane, Jr. 1979. Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge. RHO-BWI-ST-5. Rockwell Handford Operations, Richland Washington.
- Gibs, J. and T.E. Imbrigiotta. 1990. Well Purging Criteria for Sampling Purgeable Organic Compounds. Groundwater, Vol. 28, No. 1, pp. 68-78.

- Hardin and Gilbert. 1993. "Comparing Statistical Tests for Detecting Soil Contamination Greater Than Background." Prepared for US Department of Energy Under Contract DE-AC06-76RLO 1830. December.
- Philip Environmental Services Corporation. 1995. Soil Vapor Extraction Treatability Study. Technical Memorandum. September.
- Philip Environmental Services Corporation. 1996. Drummed Waste Characterization Study. Technical Memorandum. January.
- Podoll, R.T., H.M. Jaber, and T. Mills. 1986. Tetrachlorodibenzodioxin: Rates of Volatilization and Photolysis in the Environment. *Environmental Science Technology*. Vol 20, no. 5. pp 490-492.
- Tanaka, H.H., G. Barrett, and L. Wildrich. 1979. Regional Basalt Hydrology of the Columbia Plateau. RHO-BWI-C-60. State of Washington Department of Ecology for Rockwell Hanford Operations: Richland, Washington.
- U.S. Bureau of Reclamation. 1971. Columbia basin Project, Deep Percolation as a Percentage of Water Allotment: WTL Code 493. Ephrata, Washington.
- U.S. Department of Energy. 1979. Hydrogeologic Studies within the Columbia Plateau. Washington; An Integration of Current Knowledge. RHO-GWI-ST-5, Rockwell Hanford Operations, Richland, Washington.
- US Environmental Protection Agency. 1989. "Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-Dioxins and -Dibenzofurans (CDDs and CDFs) and 1989 Update". Risk Assessment Forum. USEPA/625/3-89/016. March.
- US Environmental Protection Agency. 1992. "RCRA Groundwater Monitoring: DRAFT Technical Guidance." USEPA/530-R-93-001. November.
- Washington State Department of Ecology. 1992. "Statistical Guidance for Ecology Site Managers." Toxics Cleanup Program. August.
- Washington State Department of Ecology. 1993. Supplement S-6 "Analyzing Site or Background Data with Below-Detection Limit or Below-PQL Values (Censored Data Sets). August.
- Widness, Scott E. 1986. The low temperature geothermal resource of the Moses Lake, Ritzville-Connel Area, East-Central Washington. Master's Thesis, Washington State University.
- Woodward-Clyde, 1997. Pasco Sanitary Landfill Final Closure Plan.

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